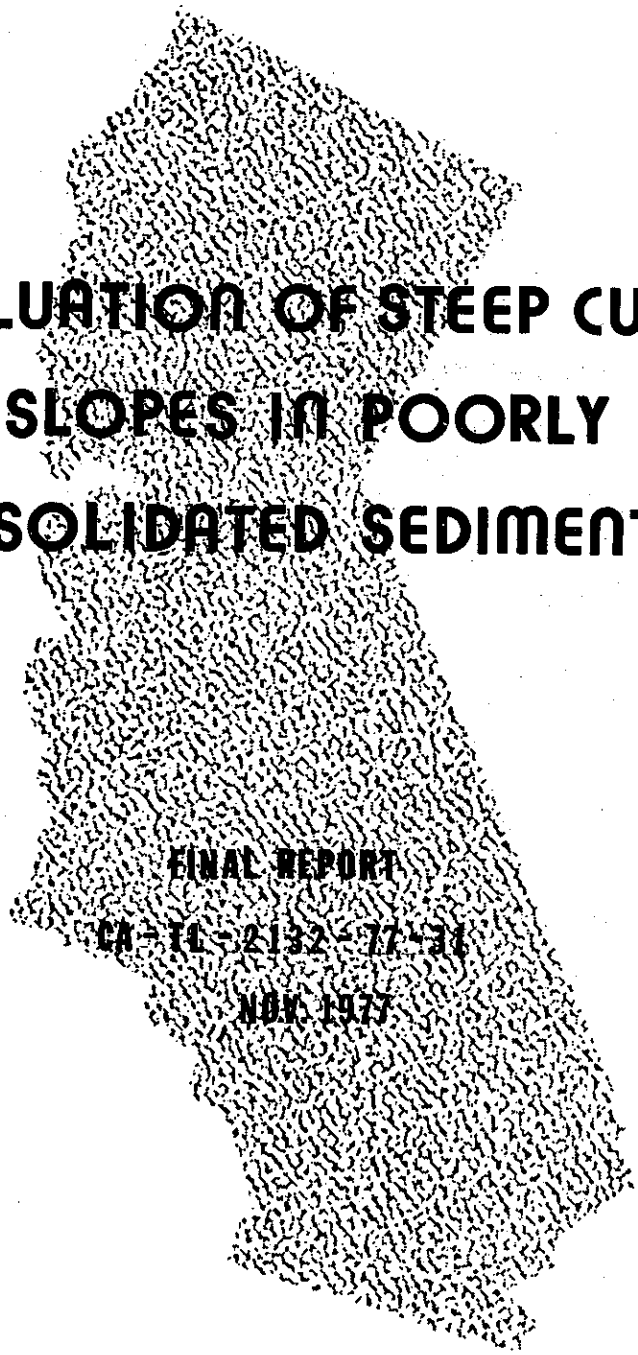
DIVISION OF CONSTRUCTION

TRANSPORTATION LABORATORY

RESEARCH REPORT

EVALUATION OF STEEP CUT SLOPES IN POORLY CONSOLIDATED SEDIMENTS



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16 ABSTRACT

The performance of newly constructed, steeply cut slopes in poorly consolidated silts, sands, and gravels along a 5 mile length of road was observed and evaluated over a 5 year period. Color aerial photography supplemented by ground level photos facilitated reconnaissance geologic mapping. The study objective was to relate damage incurred by the slopes (slides, slip outs, ravelling, etc.) to the local geology, slope ratios, bedding, and precipitation. Costs of maintenance and remedial measures incurred were determined and added to theoretical costs had flatter, more stable slopes been constructed initially. Recommendations are made for cut slope design based on findings of the study.

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Cut slope design, erosion, poorly consolidated sediments, stability, landslides.	No restrictions. This document is available to the public through the National Technical Information Service, Springfield, VA 22161.

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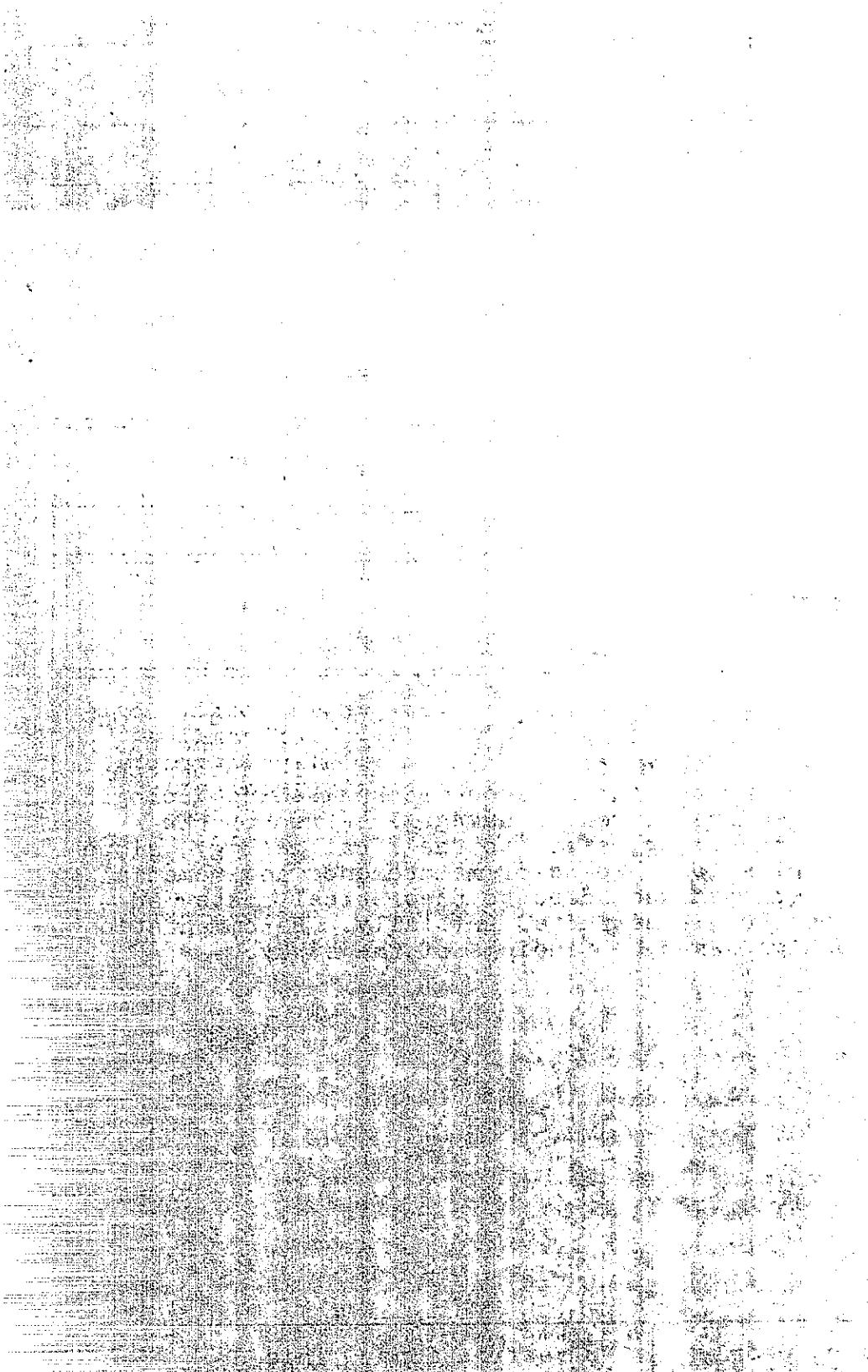

STATE OF CALIFORNIA
DEPARTMENT OF TRANSPORTATION
DIVISION OF CONSTRUCTION
OFFICE OF TRANSPORTATION LABORATORY

November 1977

TL No. 642132

Mr. C. E. Forbes
Chief Engineer

Dear Sir:

I have approved and now submit for your information this final research project report titled:

EVALUATION OF STEEP CUT SLOPES IN
POORLY CONSOLIDATED SEDIMENTS

Study made by . . . . . Geotechnical Branch

Under the General Direction of . . . . Raymond A. Forsyth, P.E.

Under the Supervision of . . . . . Marvin L. McCauley, CEG

Principal Investigator . . . . . Duane D. Smith, CEG

District Co-ordinator . . . . . Del Hollinger

Report Prepared by . . . . . Duane D. Smith, CEG

Very truly yours,

George A. Hill

GEORGE A. HILL
Chief, Office of Transportation Laboratory

Attachment

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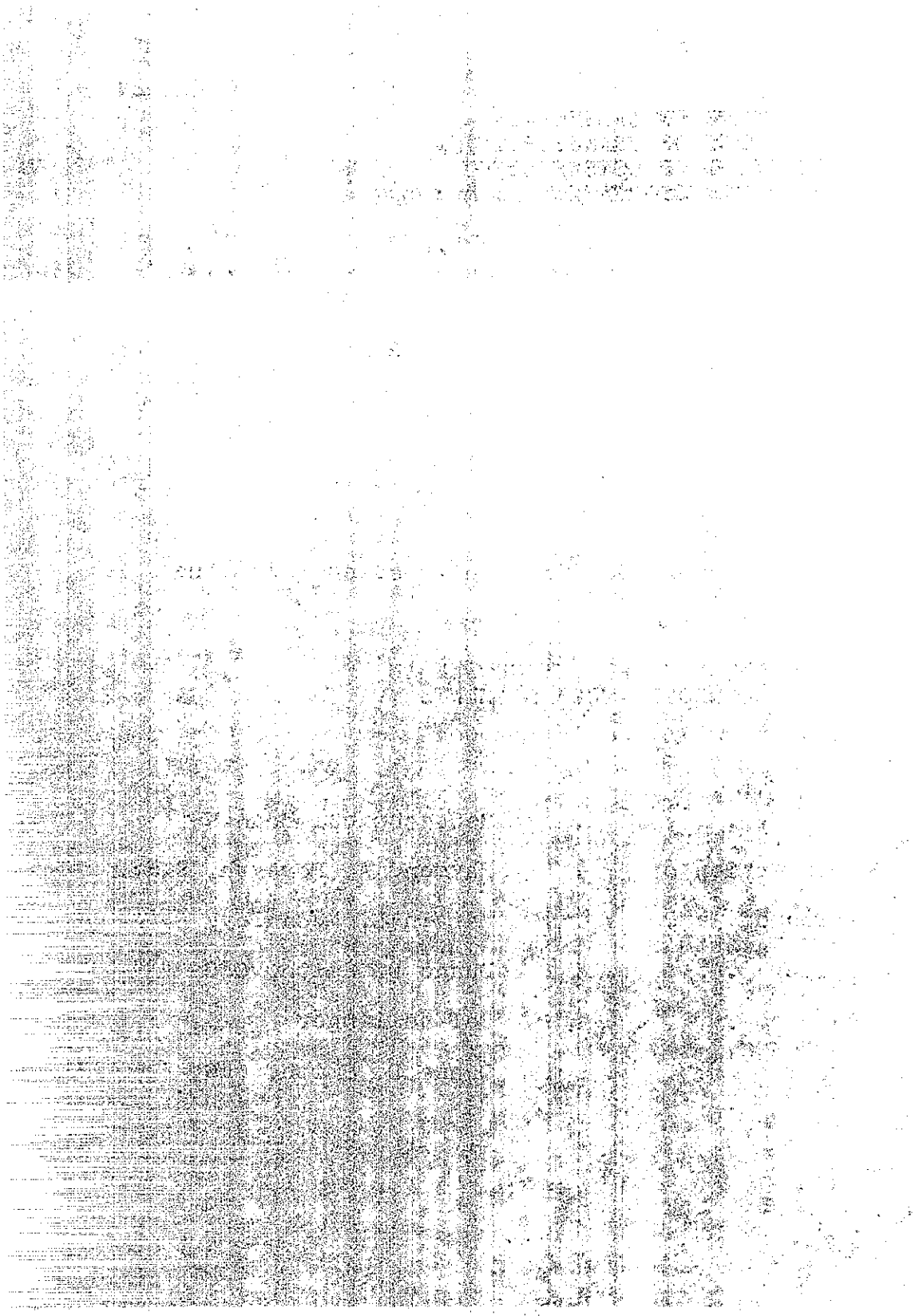


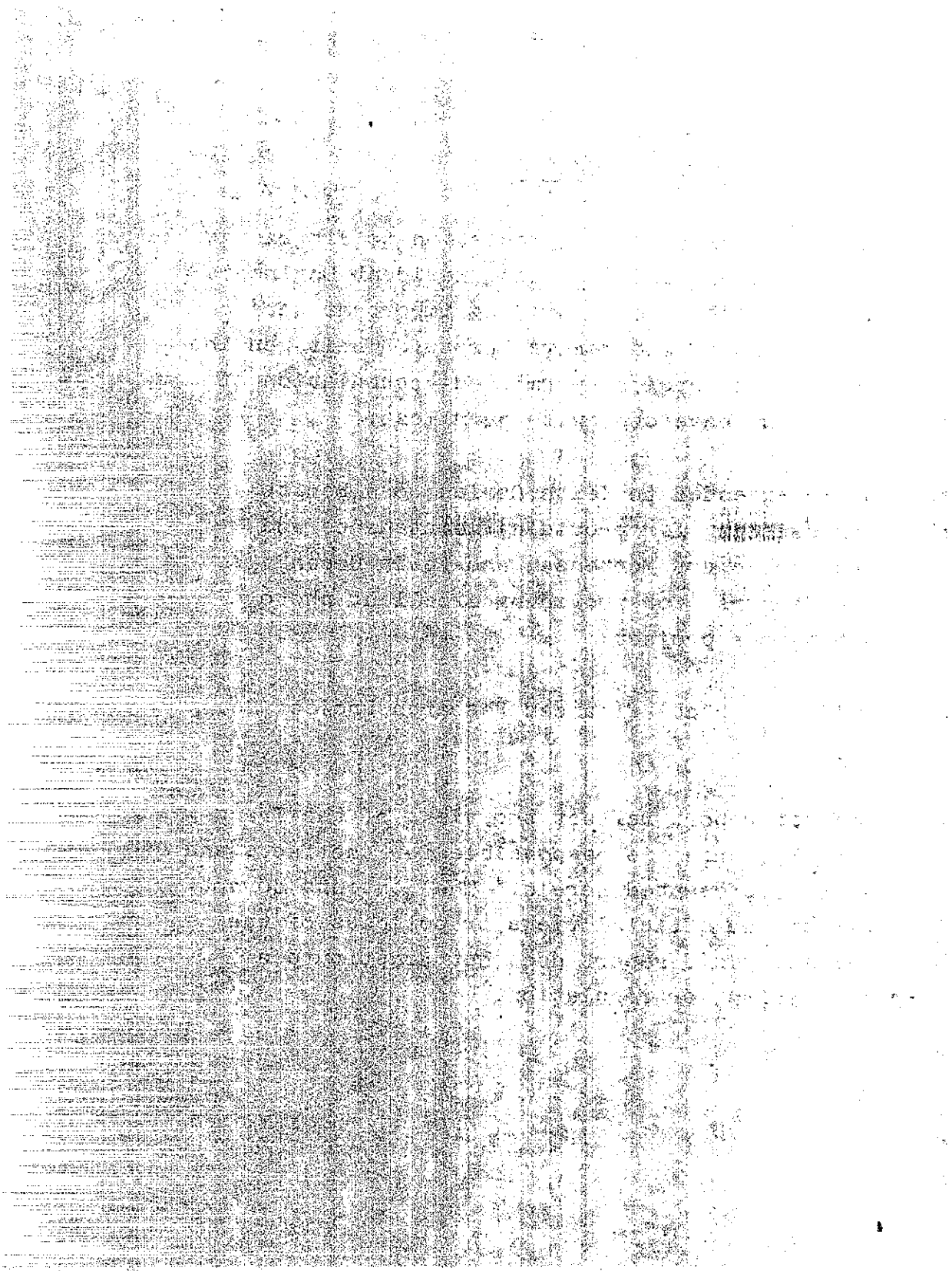
ACKNOWLEDGEMENTS

The author wishes to express his appreciation to Jim Baetge and Jim Campbell, Resident and Assistant Resident Engineers of the construction project for providing important data on slide occurrence, yardage, and removal costs. Their genuine interest in the research project permitted accumulation of information that might have otherwise been lost.

Special thanks are extended to Keith Carlen, San Benito County Road Commissioner, for providing maintenance and rainfall data and to Robert Mortensen and Lewis Green, laboratory photographers, for providing excellent photo coverage throughout the project.

This investigation was State-financed Research Project No. 642132.

The contents of this report reflect the views of the Transportation Laboratory, which is responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the State of California. This report does not constitute a standard, specification, or regulation.



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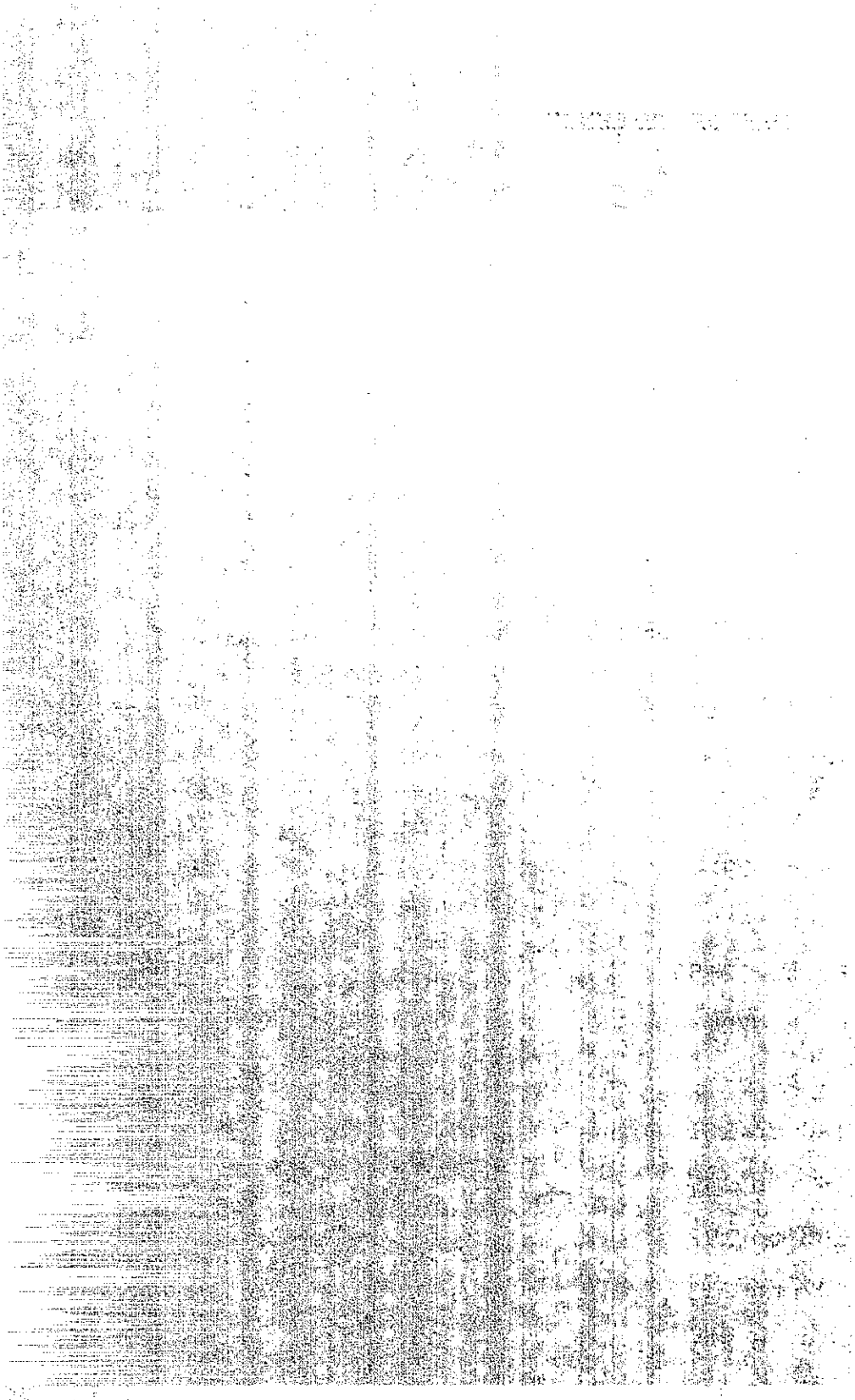

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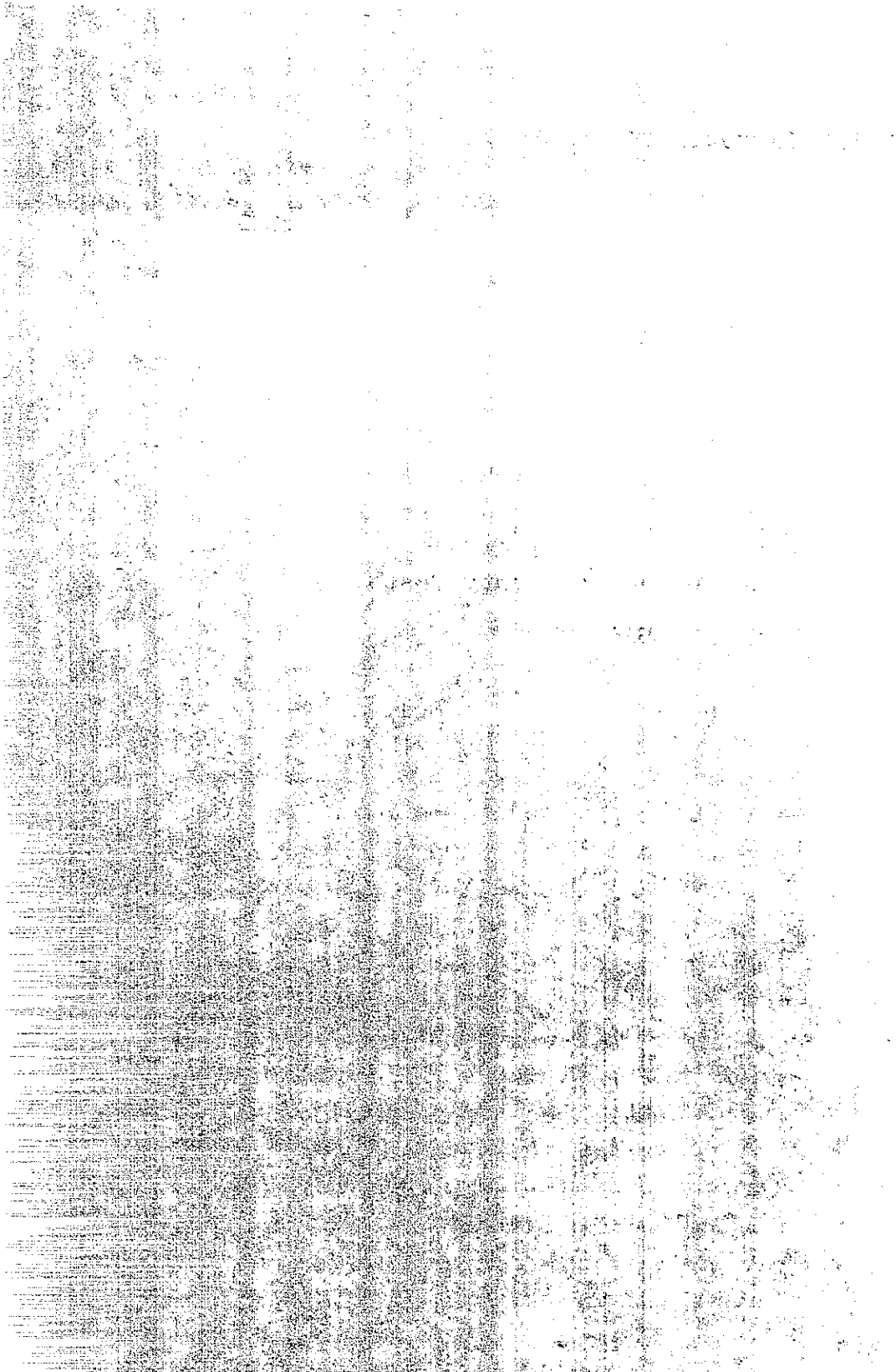


INTRODUCTION

On November 2, 1971 the Transportation Laboratory (formerly, Materials and Research Department) was requested to commment on proposed cut slope designs for County Road 05-SBt-1193-CR, Panoche Road, as contained in the P S & E report, dated September 22, 1971 (see Location Map). The designs consisted generally of 3/4:1 cut slopes with 15 foot wide benches above grade where the cut height exceeded 40 feet. In reply, the Laboratory expressed the viewpoint that the proposed slope ratios appeared to be too steep for stability based upon past experience with the materials through which the cuts were to be constructed.

The project slope designs were subsequently discussed at a meeting held in Sacramento on December 1, 1971, attended by Mr. Keith Carlen, San Benito Count Road Commissioner and representatives of District 05, Department of Transportation Headquarters, and the Transportation Laboratory. During this meeting Mr. Carlen requested that Translab conduct a field review of the project.

The review was made on December 10, 1971 by two engineering geologists of the Translab Geotechnical Branch. The geologists concluded that the proposed 3/4:1 slopes would be subject to heavy raveling, sloughing, and that some would possibly fail during construction or the following winter. They proposed modification of designs to flatter configurations as listed on Table 1 of this report. The alternatives suggested were considered the steepest that would be built with a reasonable assurance of stability along the project.

After considerable discussion a decision was made to construct the slopes as originally designed by the County, with a few exceptions. The designs of two slopes were flattened and a third was steepened prior to construction (see Table 1). In the Special Provisions stepped slopes were listed for five of the slopes as an optional design.

In the view of the Transportation Laboratory the Panoche Road project presented an excellent opportunity to study the performance of over steepened cut slopes in poorly consolidated sediments. A State-financed research project was therefore initiated to permit observation of their long term performance. A 5 year period was selected since rainfall is highly variable in the subject area.

Color aerial photographs on a scale of 1"-500' and 1"=1000' were taken of the project area prior to construction for reconnaissance geologic mapping. Ground level photographs were also taken along centerline prior to construction.

Computations of the yardage differential between the San Benito County design and the Translab design were made using the District 05 computer program set up for the project.

The construction operation was inspected and photographed during all phases. Areas of instability were defined and documented in detail. A tabulation of slide removal and slope correction yardage and costs was maintained.

Costs incurred that could be attributed to large-scale sliding, such as purchases of additional right-of-way, traffic control, temporary detours, and repair of fencing, were determined and tabulated during the construction phase.

Visits to the job site were made periodically through five successive winters. The condition of the cut slopes was noted and photographed. Maintenance costs were obtained with the assistance of County forces.

CONCLUSIONS

The following findings and conclusions are based upon analysis of the data developed in this study.

1. The 3/4:1 slope design used in poorly consolidated sediments generally failed, especially in cuts over 40 feet in height. 3/4:1 cut slopes in slightly cemented sandstone performed better than 3/4:1 slopes in slightly cemented siltstone. 3/4:1 cut slopes in siltstone performed better than those in claystone or mudstone. 3/4:1 cut slopes performed well in slightly cemented gravels; however, where such cementation was lacking, they failed.

2. All benches constructed above grade failed. Unbroken slopes with benches at grade to handle ravel and sloughing would appear to be a preferred design for materials such as encountered within this project.

3. South-facing slopes were more subject to erosion than were slopes having other orientations, due to storm patterns. North-facing slopes with beds and clay seams dipping into the roadway were more subject to sliding than were slopes having other orientations.

4. Stepped 1:1 slopes in terrace gravels performed well. Treads and risers of stepped slopes in the Paynes Shale and Sandstone were too large and are still visible after a 5 year period.

5. On the basis of economics alone, there was a close balance between additional initial cost of flatter slope design and the slide removal and cleanup cost of the steep design.

6. Right-of-way fencing was frequently undermined as the result of placing the fences too close to the top of cuts or partially buried when placed too near toes of embankments.

7. Two road closures caused by sliding would have created a much higher risk factor on a State highway because of the greater volumes of traffic involved.

Most slide corrections consisted merely of debris removal. On State highways failing, slopes are often flattened, warped, buttressed, dewatered, or a combination of these, which constitutes more extensive and costly treatment. Thus slide correction costs are not considered representative of those which would have been incurred had the roadway been a state highway.

IMPLEMENTATION

The findings of this report will be forwarded to all California Transportation Districts and can be used as a guide when designing slopes in poorly consolidated sediments. Copies of this report will be supplied to other State and Federal Agencies upon request.

DISCUSSION

A. CONSTRUCTION HISTORY

The original construction contract was awarded to Turnkey Enterprises on June 14, 1972 with a completion date of November 29, 1972. Actual work on the project began on July 24, 1972. This contract was terminated by the State in October because of lack of progress. The Gold Coast Construction Company was hired to complete the work but subsequently abandoned the project and the Marvin Mims Company later completed the work. Due to these difficulites with contractors, the project was not completed until July 25, 1973, some 8 months later than scheduled.

B. PRECIPITATION

Accurate rainfall data for the project area were not available. The closest weather station in operation during most of the period covered by this study is located in Hollister, California, some 16 air miles northwest of the area (see location map, Figure 1). Rainfall data for July, 1976 through May, 1977 were obtained from the San Benito County Road Department gauge located approximately 5 miles south of Hollister. Average rainfall for Hollister is 13.27 inches, while the project area receives considerably less according to unofficial records. The following table shows the annual precipitation recorded and the deviation from the normal.

Year	Recorded Precipitation (in.)	Deviation from Normal (in.)
1972	10.50 (1)	-2.77
1973	19.70 (1)	+6.43
1974	11.80 (1)	-1.47
1975	10.60 (1)	-2.67
1976	12.34 (2)	-0.81
1977	9.38(through May)(2)	-3.89

(1) Hollister Weather Station
(2) San Benito County Road Department gauge

It should be noted that rainfall amounts were below normal during these years, with the exception of 1973. During the winter of 1973, the project was in a state of partial completion and many landslides and slope failures occurred.

C. GENERAL GEOLOGY

There are two significant lithologic units that form the cut slopes in this area. The major portion of the project, Sta. 0+00 to Sta. 238+75, is constructed in the San Benito Gravels of the Plio-Pleistocene age. From this point to the end of project, Sta. 271+00, slopes have been constructed in the Paynes Shale and Sandstone Member of the Panoche Group of Upper Cretaceous Age.

An occasional deposit of terrace gravel of Recent Age can be found in cut slopes along Tres Pinos Creek, Sta. 207 to Sta. 271.

San Benito Gravels are a thick series of non-marine deposits that blanket much of the northwestern part of San Benito Quadrangle. They rest with angular discordance upon the Cretaceous sediments and have been subjected to gentle folding and faulting of comparatively small displacement.

These sediments consist of gravels, sands, silts and clays; in part consolidated into conglomerate, sandstone, siltstone and clay shale, or mudstone (Photos 1, 2 and 3). Sorting is generally poor and rapid variations in grain size occur both laterally and vertically. Channeling and rapid lensing of gravel layers are prominent features.

Clays, mudstones, and siltstones occur in distinct beds; or are intermingled with beds of sand and gravel. They are soft, brownish to blue in color, and poorly cemented and bedded. "Badland" topography has developed in these soft units in the vicinity of Sta. 74 (see Photo 3). These sediments are unstable and subject to intense erosion. Most of the landslides on this project occur within these incompetent sediments.

Poorly cemented sandstones of the San Benito Gravels are usually more stable than the finer sediments and stand well on steeper slopes. When they erode they often produce a fluted effect (see Photo 2).

Pebbles and cobbles in the gravel and conglomerate layers range from a few inches to a foot or two in diameter (see Photo 1). Where slightly cemented they stand well on steep slopes. However, where cementation is lacking, they have a tendency to ravel extensively.

The Paynes Shale and Sandstone Member consists of interbedded dark clay-shales, greenish sandstones, and grayish limestone. They are typically greenish to black clay-shales or poorly sorted micaceous silty shales. They are poorly to well-bedded and interbedded with the sandstone.

The sandstones are poorly sorted arkoses that contain considerable greenish to brown biotite. They occur in well-cemented beds ranging from a few inches to 3 feet in thickness. The limestones are generally grayish in color and occur as concretions or in small lenses a fraction of an inch to a few inches in diameter. Sliding is not a major problem in this member but was noted in steep slopes that exhibited shearing as a result of past seismic activity.

D. INDIVIDUAL CUT SLOPE DESCRIPTIONS AND EVALUATION

1. Sta. 7+50 to 10+25

This 120 ft. high sidehill cut was constructed on a 3/4:1 slope with two 15 ft. wide benches above grade at 40 ft. intervals (Photos 4 through 9). Buff colored interbedded siltstone and sandstone on either end of the cut stand well on the 3/4:1 slope. A broad band of blue-gray claystone strikes diagonally across the middle of the cut face. Failures in this material began during construction (see Photos 4 and 5) and have continued to occur throughout the 5 year study period. A talus slope can be observed on the 6 ft. wide bench at grade (Photo 7).

The centers of both benches above grade have been breached by sliding (Photo 9). In time these benches will be destroyed by mass wasting. Photos 6 and 8 show cracking well developed which will lead to further small slides in years to come. The fence located at the edge of the top of cut will have to be moved in the future because of breakage along the edge.

Approximately 700 to 1000 cubic yards of material was lost during construction. The roadway was closed to traffic by

slide debris one night and most of the next day (see Photo 5). No slide correction has been made. Debris is removed from the base as it accumulates.

The San Benito County Road Commissioner stated that maintenance records of slide removal are not recorded for each individual cut. Therefore, an estimate of additional slide yardage since the project was accepted by the County could not be made.

The constructed benches were lost and the 3/4:1 slopes failed. As a result of observations made during this study, a 1 1/2:1 cut slope with a 20 foot wide debris bench at grade would be recommended for this area.

2. Sta. 15-17

This 30 ft. high sidehill cut was construction on the left using a 3/4:1 slope design (Photo 10). Materials consist of brown to buff siltstone and claystone. Minor sliding and considerable sloughing of the claystone (see Photo 11) has produced a loss of approximately 75 cu. yds. of material over the 5 year period.

Based on our observations, an unbroken 1:1 design would be recommended. Planting and watering the slope until vegetation could become well established would have reduced the sloughing considerably.

3. Sta. 18-23

A 3/4:1 slope design was used on this 35 ft. high through cut. Although both the left and right cut slopes are composed of clayey siltstone and weakly cemented silty sandstone, slope

performance was different. Several small slides and popouts developed on the right or north facing slope (Photos 12 and 13) while gulleying and erosion was more characteristic of the left or south facing slope (Photos 14 and 15).

Winter storms move across the area from south to north and thus the south-facing slopes are more susceptible to erosive wind and rain.

Inclined clay seams dip into the roadway from the right cut slope. Popouts have occurred where the slope design has undercut these seams.

A 1 1/4:1 slope design would probably have eliminated or greatly reduced the number of popouts and would have been more receptive to revegetation. A temporary erosion control technique such as a spray-on hydromulch with seed and fertilizer would have reduced the slope erosion.

4. Sta. 25-29

This cut is similar in most respects to conditions found between Sta. 18 and 23 (see Photos 16 through 21), except that erosion may be slightly more severe and sliding and popouts more numerous. Based on the 5 year observations, a 1 1/4:1 treated slope would be recommended in this area.

5. Sta 44-47

Some minor sliding and erosion have occurred on this 35 foot high cut slope (see Photo 22). Although a slightly flatter slope would probably have been more satisfactory, sloughing and erosion would still have taken place. County forces cut

a bench some distance above the top of slope after the project was completed to permit a local rancher to move his cattle more easily from one side of the ridge to the other (Photo 22).

6. Sta. 50-52+50

Shortly after construction a bedding plane failure was apparent near grade on this 62 ft. high benched cut (Photo 24). Ten days later (Photo 25) the failure had progressed to the bench 40 ft. above grade. Some slope loss was also noted at that time from the bench to the top of cut. Photo 26 shows the failed cut as it looked in April 1977. It appears that this slope will continue to fail until the bench has been totally removed and a 1 1/4 or 1 1/2:1 slope has been established.

Poorly consolidated and cemented sandstone and siltstone were underlain by soft, unconsolidated claystone. Loss of this incompetent material by mass wasting undermined the overlying sediments, which then failed. A 1 1/4:1 slope design would be recommended in this area based on the 5 year study.

7. Sta. 64-72

A pocket of unconsolidated gravel overlying buff punky sandstone failed on the 3/4:1 slope left of Sta. 65+75 during construction (Photos 27 and 28). Four fence posts were undermined and left suspended (Photos 27 and 44). Raveling of blue claystone (Photo 29), and sliding on an inclined clay seam are now occurring (Photo 30).

The highest portion of the cut, Sta. 67 to 72, was originally planned at 3/4:1 with a bench 40 ft. above grade. During construction the bench was eliminated resulting in an approximate 1.1:1 cut slope. Although the slopes are generally stable, a 1 1/4:1 would probably eliminate all but the raveling at this location.

8. Sta. 91-94)

Originally a 3/4:1 benched slope was designed for this 53 ft. high cut. During construction the bench was eliminated resulting in a 1.1:1 slope. This design was performed well except for a considerable amount of raveling (see Photos 31 and 32) of the blue claystone.

9. Sta. 130-131

This 10 ft. high 3/4:1 slope has performed well in slightly cemented siltstone.

10. Sta. 141-147

A 3/4:1 slope was constructed in poorly consolidated siltstone.

In June 1973 the slope failed completely and was reconstructed at a 1 1/2:1 ratio (Photos 33 and 34). This slope modification generated approximately 8,000 additional cubic yards of earthwork. The new slope performed well until February of 1975. At that time movement along a clay seam that dips into the roadway was noted (Photo 35). It is anticipated that this movement will continue and that the slope above the plane will eventually fail completely.

Because of the dipping component of the clay seam into the raodway prism, a 2:1 design is indicated at this location.

11. Sta. 188-192

A 25 ft. high 3/4:1 slope failed at this site during the latter stages of construction. Approximately 2500 to 3000 yards of slide debris were removed and the slide scarp was

warped into the existing slope (Photos 36 and 37). The correction has been successful although there has been a minor buildup of siltstone debris at the base of the slope. A 1 1/2:1 slope might have proven stable in the poorly cemented siltstone at this location.

12. Sta. 207-213

Stepped slopes were constructed on this 25 ft. high 1:1 slope. Approximately 50 yds. of gravelly terrace deposits slipped out near the top of cut, (Sta. 211) during construction (see Photo 38). Apart from this small failure, the cut slopes, both left and right, have performed well. Most of the steps have disappeared now leaving the former treads more heavily vegetated than the risers. (Photo 39). On the eastern end of the cut steps are more prominent in the slightly cemented gravels than in the sandy siltstone.

13. Sta. 239-245

Three-quarter to one stepped cut slopes were constructed in sheared broken shale of the Paynes Shale and Sandstone Member to a height of 46 ft. at this site (Photo 40). The cut slope also contains some terrace deposits of slightly cemented gravel (Photo 41).

The slope on the left has failed and will probably continue to flatten to an approximate 1 1/2:1. There is continual raveling at the bottom and the fence will have to be moved back at the top. A 1 1/2:1 slope would have been a more suitable design on the left. However, the 17 ft. high 3/4:1 stepped slope on the right is performing well.

14. Sta. 262-267

Poorly bedded shale with minor sandstone is exposed on the face of the 65 foot high 1 1/4 stepped slope on the left (Photo 42-43). The planned 3/4:1 slope and bench were eliminated prior to construction and steps having a 4 foot riser and a 3 foot tread were used. The slope on the right is stepped on a 3/4:1 ratio (Photos 44 and 45).

Overall the slope design both left and right is performing well. Where hard sandstone was encountered, (see Photo 45), the steps are broken and ragged. The steps were constructed with a 4 ft. riser and a 3 ft. tread. Steps with smaller dimensions would have been appropriate for this material.

E. COST ANALYSIS

1. Contract Change Orders

Contract change orders relating directly to slope stability problems, such as slide removal and clean up, fence removal and replacement, contaminated subbase and similar items, totaled just under $40,000 (see Table 2). This work was done by the contractors and was paid for with project funds.

2. Fencing

Placement of the wood-post and barbed-wire right-of-way fence was completed by County forces prior to construction. In many cases this fence was placed within a foot or two of the top of cut or toe of embankment (Photos 46, 47, and 48).

Rock that rolled during placement of embankment often over ran the fence requiring clean up of private property by the

contractors. Sliding and minor failures undermined the fence in many places, requiring relocation. In some cases the contractor repaired or relocated fences. These costs are included in the change orders, Table 2.

In most cases the fencing placed by the contractor was temporary and was replaced by County forces after the contractor had left the area.

An estimated $1,000 was spent on this fence work based on the $1.00 per foot figure supplied by the County.

3. Right-of-Way

Sliding in the vicinity of Sta. 65 to 67, Sta. 142 to 147 and Sta. 188 to 192 required the acquisition of additional property. A condemnation suit was planned by the County for the additional real estate needed near Sta. 65, since the property owner was not willing to sell the land. Mr. Carlen later stated that the suit was dropped and that the property owner did in fact donate the needed land to the County. Additional land was also donated by the respective owners at the other two locations. The County therefore has not spent any additional funds on the purchase of land because of stability problems.

4. Maintenance

Maintenance costs per mile of road in San Benito County are approximately $1,000 per year. This figure includes a seal coat on the road surface. There have been no major maintenance problems on the section of road described in this report since the project was accepted.

Slide removal costs or yardage tabulations have not been kept on this project. The road is patrolled twice a day by maintenance crews who blade rock or ravel off the traveled way when necessary.

Many locations will require relocation of the right-of-way fence in the future. An example is the first cut on the project, Sta. 7+50 to Sta. 11, where progressive failure will undermine the fence in the next wet season or two.

Fencing costs in 1973 were approximately $1.00 per ft. which included materials and labor. Fencing cost today for the same type of fence is approximately $2.00 per foot.

5. Cost Summary and Evaluation

The bid price for roadway excavation was $0.54 per cubic yard. An additional 100,000 cubic yards of excavation would have been required if the flatter slope design recommended by Translab had been used. This figure is derived from planimeter values obtained from computer cross-sections developed by the District office under the supervision of Mr. Del Hollinger, District Co-ordinator for this study.

Based on the figures of $0.54 per yard and 100,000 cubic yards of additional excavation, it would have cost $54,000 more to construct the flatter slope design, excluding right-of-way costs.

Right-of-way costs for this project are difficult to determine. In 1972 grazing land in this area sold for an average of $500 per acre. It is the author's understanding, however, that much of the land needed to widen or realign the roadway was donated by the ranchers in the interest of receiving an improved road.

Maintenance costs must have been somewhat higher for the first two years after construction than they had been previously. Fencing costs were higher than normal since much of that placed by the contractor was temporary, with the understanding that the County would replace it with permanent fencing after the project was completed.

The $40,000 of change orders for landslide removal and clean-up coupled with the increased maintenance and fencing costs for the first 2 or 3 years comes to an estimated $51,190.00 (see Table 2), which is roughly equivalent to the $54,000 required for a flatter slope design. Had not the slopes been flattened and benches eliminated at Sta. 64 to 72, 91 to 94 and 263 to 267 during construction, the cost would probably have exceeded the $54,000.

6. State Costs Compared to County Costs

Landslide corrections on this project both during and after construction were limited to removal of slide debris (see Photos 7, 27 and 28). No attempt was made to smooth or reslope the faces. Two exceptions are the slides at Sta. 141 to 147 and Sta. 188 to 192. The first was resloped to a 1 1/2:1 (see Photo 34) and the second slide plane was warped into the existing cut face (Photo 37) to provide a more pleasing appearance.

If this project had been constructed as a State highway, most if not all the failed slopes would have been resloped or modified to reduce future maintenance costs, future risk, and produce a more pleasing appearance. This procedure would have involved considerably more yardage and, consequently, would have been much more expensive.

State-right-of-way costs for purchasing a parcel of land run between $700 and $1,000 per parcel. In all likelihood, additional land donated by the ranchers to the County would have had to be purchased by the State. In other areas where minor fence adjustments have been, or will be made, similar costs would probably be incurred by the State.

F. DESIGN SUMMARY AND EVALUATION

In most cases the 3/4:1 slope design proved inadequate. This is particularly true of slopes that exceeded heights of 30 to 40 feet. The suggested design based on the 5 year evaluation is indicated for each cut on Table 1. This design is in most cases flatter than the county proposal, and in some cases steeper than the original Transportation Laboratory proposal.

Benches failed on all cuts where employed. Distress was evident in each case before the construction contract was completed. Wider debris benches placed at grade to handle rockfall and ravel would have been an ideal solution, design-wise.

Two road closures were caused by sliding of overly steep slopes during construction. Although there was some risk to the traveling public, the county took the position that low traffic index did not merit the associated costs of a flatter design. Because a State highway usually has a much higher traffic index than the subject roadway, it would have a much higher risk factor.

The ragged and eroded slopes on the project are now displeasing in appearance. In time, the sharp gullies will broaden and round out, eventually taking on the appearance of the surrounding countryside.

Economically, the costs of the steeper designs with their associated stability and erosional problems and a flatter design with fewer landslides nearly balanced out. It should be pointed out, however, that had the same project been constructed as a state highway, landslide correction would have been much more extensive than simply debris removal and, therefore, much more costly. Right-of-way costs would have also been probably higher on a state project.

It should be pointed out, however, that there would probably have been some failures even with the flatter design slopes.

Erosional control techniques such as a spray-on application of hydromulch fiber with seeds and fertilizer would have greatly reduced the sloughing and erosion of the San Benito gravels.

Cut slopes in the Paynes Shale and Sandstone Member performed better than those in the unconsolidated sediments. It is the author's opinion, however, that steps with smaller dimensions should have been used in the shale. Erosion was not a serious factor in the sheared and broken shale and sandstone.

Of the San Benito Gravels, the slightly cemented sandstone unit generally performed better than the siltstone, and the siltstone better than the clay or mudstone. Interbedded siltstone and claystone performed poorly. The incompetent claystone is subject to severe sloughing. Once this occurs in a bedded situation, the siltstone or sandstone is no longer supported and lacks the strength to stand alone.

Pockets and lenses of unconsolidated gravels invariably failed. Where the gravels are slightly cemented, they stand well on 3/4:1 slopes.

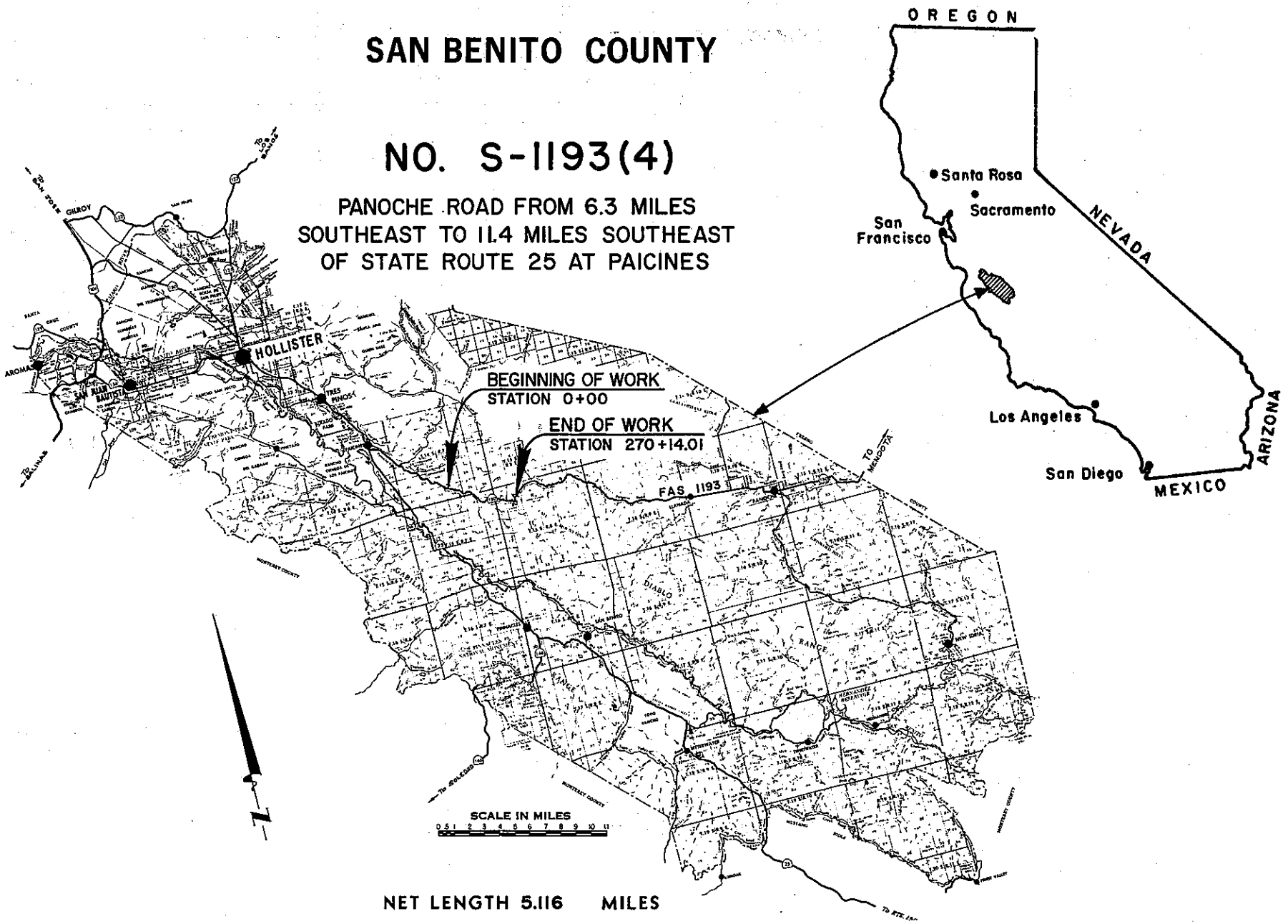


Figure 1

Table 1

CUT SLOPE RECOMMENDATIONS

Approximate Station	Initial County Proposal May 1970	Translab Recommendation Dec. 1971	Final County Proposal Feb. 1972	As Built July 1973	Suggested Design Based on 5 yr. Evaluation June 1977	Comments
7+50 to 11	3/4:1 Benched	1 1/2:1	3/4:1 Benched	3/4:1 Benched	1 1/4:1, 20 ft debris Bench of grade	
15-17	3/4:1	1 1/2:1	3/4:1	3/4:1	1:1	
18-23	3/4:1	1 1/2:1	3/4:1	3/4:1	1 1/4:1	
25-29	3/4:1	1:1	3/4:1	3/4:1	1 1/4:1	
44-47	3/4:1	1:1	3/4:1	3/4:1	1:1	
50-52	3/4:1 Benched	1 1/4:1	3/4:1 Benched	3/4:1 Benched	1 1/4:1	
64-72	3/4:1 Benched	1 1/4:1	3/4:1 Benched	1.1:1	1 1/4:1	Slope changed and bench eliminated during construction
91-94	3/4:1	1:1	3/4:1 Benched	1.1:1	1:1	Slope changed and bench eliminated during construction
130-131	3/4:1	3/4:1	3/4:1	3/4:1	3/4:1	
141-147	3/4:1	1 1/2:1	3/4:1	3/4:1	2:1	Slide correction flattened slope to 1 1/2:1
188-192	1 1/2:1	3/4:1	3/4:1	3/4:1	1 1/2:1	
207-213	2 1/2:1	1:1	1:1	1:1 Stepped	1:1 Stepped	Stepping given as alternative in Special Provisions
239-245	1 1/2:1	3/4:1	3/4:1	3/4:1 Stepped	1 1/2:1 Lt 3/4:1 Rt	" " "
263-267	1 1/2:1	1 1/4:1	1 1/4:1 Lt 3/4:1 Rt	1 1/4:1 Lt 3/4:1 Rt Stepped	1 1/4:1 Lt 3/4:1 Rt	" " "

Table 2

Station	CCO#	Work Performed	Cu. Yds.	Cost	Date	Remarks
Misc.	1	Slide removal	none listed	$ 500.00		
	10	Various	11,000	14,399.25	4-10-73	
241+50		Slide removal		260.00	4-10-73	Equip. & labor.
50+00				149.00	4-11-73	A lot of fence removed for disposal of excess yardage. This fence replaced by County forces.
Misc.		Slide cleanup		400.00		
55-61+00		Slide cleanup		345.00	4-16-73	Equip. & labor.
138+00		Slide cleanup		155.00		
145+00		Slide cleanup		160.00		
55-60				203.00	4-18-73	
144+00		Slide removal & fence		200.00	4-27-73	$50 of the $200 for fence removal.
Misc.		Slide cleanup		650.00	5-1-73	
Misc.		Slide cleanup		700.00	5-3-73	Mainly gradeall work.
Misc.		Slide cleanup		617.00	4-12-73	
144+00		Slide removal		550.00	5-2-73	
9+50		Slide removal		311.00	5-7-73	
142+00		Slide removal		680.00	5-8-73	

Table 2 (con't.)

Station	CCO#	Work Performed	Cu. Yds.	Cost	Date	Remarks
192+00		Slide removal & fence		$ 450.00	5-9-73	$90 of the $450 was for fence.
192+00		Slide removal		425.00	5-10-73	
192+00		Slide removal		425.00	5-11-73	
192+00		Remove fence		130.00	5-14-73	
192+00		Slide removal		906.00	5-14-73	
192+00		Slide removal		1,586.00	5-15-73	
192+00		Fence		176.00	5-16-73	
192+00		Slide removal		1,390.00	5-16-73	
192+00		Slide removal		288.00	5-16-73	
192+00		Fence		264.00	5-17-73	
192+00		Slide removal		1,000.00	5-17-73	
192+00		Fence			5-18-73	
192+00		Slide removal		363.00	5-18-73	
192+00		Fence		177.00	5-21-73	
192+00		Fence removal		244.00	5-22-73	
192+00		Fence		89.00	5-23-73	
142+00		Fence		177.00	5-29-73	

Table 2 (con't.)

Station	CCO#	Work Performed	Cu. Yds.	Cost	Date	Remarks
142+00		Fence		$ 60.00	5-30-73	
210+00		Slide removal		38.00	5-30-73	
Misc.		Slide removal		40.00	6-7-73	
Misc.		Slide removal		157.00	4-24-73	
192		Fence		212.00	5-17-73	
192		Fence		207.00	5-18-73	
143 to 146+50	22	Slide Removal	8,000	7,096.00	6/26-7/6/73	Additional property to be purchased by County later. County replaced fence twice.
143 to 146+50	23	Replace contaminated sub-base due to sliding		1,711.00	5-28-73	
		Total Change Orders		$39,890		

Other Costs (Estimated)

Various	Slide removal	$ 2,000.00	7-23-73	Time extension costs (State Personnel)
150	Replace drop inlet damaged by slide removal	300.00	5-28-73	Inlet supplied by County
Various	Temporary fencing provided by County	1,000.00	Various	

Table 2 (con't.)

Station	CCO#	Work Performed	Cu. Yds.	Cost	Date	Remarks
Other Costs (Estimated) con't.						
Various		Permanent fencing placed after construction by county		$ 1,000.00	Various	
8-11+50 188-192		Road closure expenses, signs, traffic control, etc.		2,000.00	2-14-73 3-26-73	
Various		Miscellaneous slide related costs incurred by County after construction		5,000	7/73-7/77	
		Grand Total		$51,190.00		

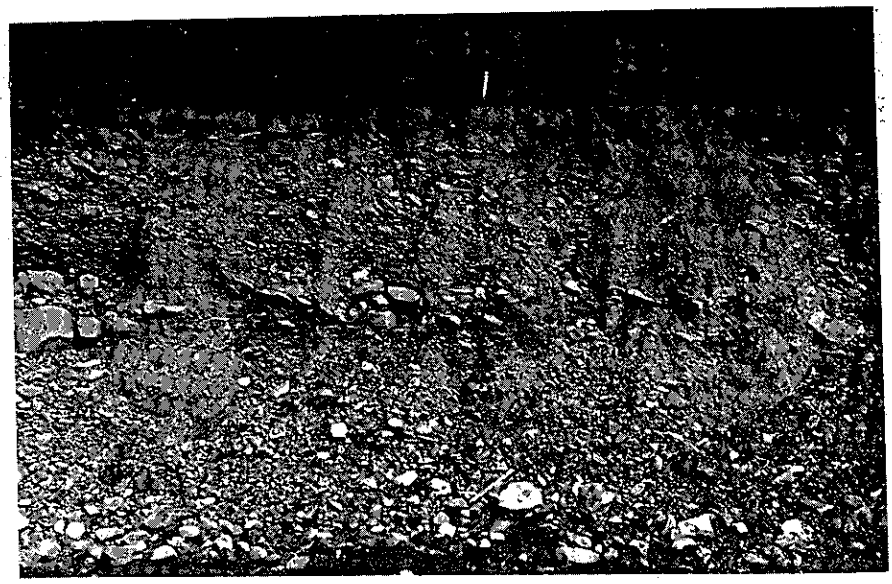


Photo 1

Gravel Unit of San Benito Gravels
2/16/73

Photo 2

Slightly Cemented Sandstone
Unit of San Benito Gravels
7/15/72

Photo 3

Silty Clay and Mudstone Unit
of San Benito Gravels
7/18/72

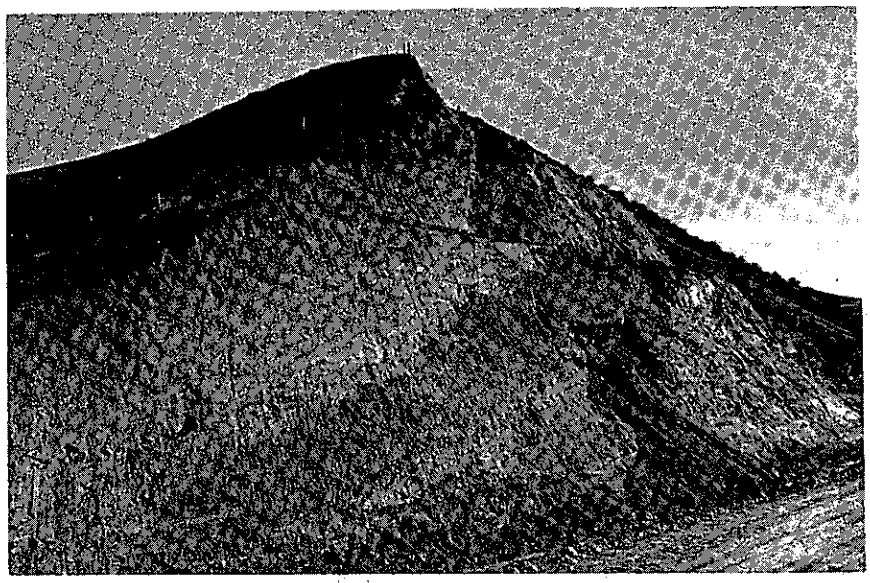


Photo 4

Sta. 7+50 to 11+00. Photo taken shortly after construction. Note beginning of failure in blue claystone unit.
2/6/73

Photo 5

Sta. 7+50 to 11+00. Failure closed roadway 7 days after Photo #4 was taken. Note slide debris pushed to side to reopen roadway.
2/16/73

Photo 6

Sta. 7+50 to 11+00. Photo taken midway through project. Note cracking on first bench and near man standing on second bench.
10/16/74

Photo 7

Sta. 7+50 to 11+00. Photo taken 3 years after Photo 6. Note debris buildup at base of slope due to raveling.
4/7/77

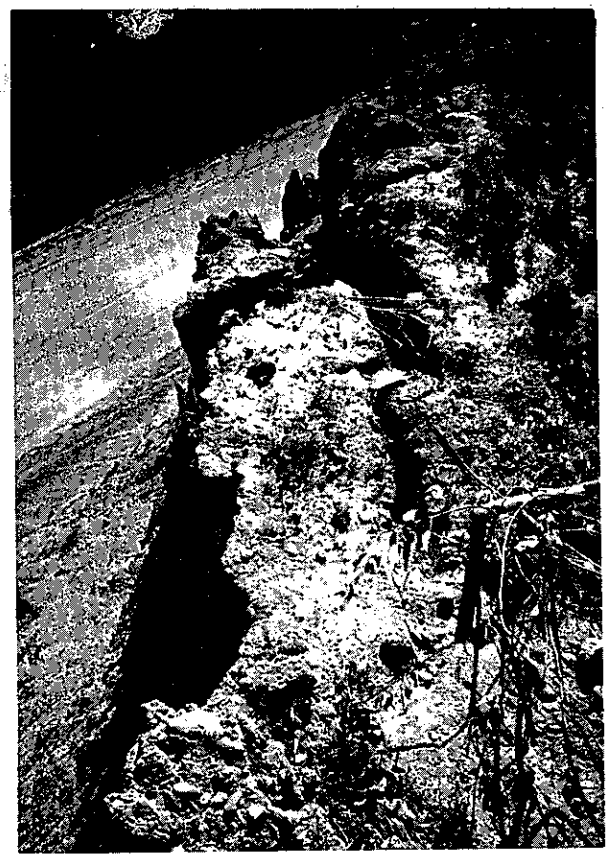


Photo 8

Sta. 7+50 to 11+00. View of cracking from first bench.
4/7/77

Photo 9

Sta. 7+50 to 11+00. Failure of second bench above roadway.
4/7/77

Photo 10

Sta. 15+00 to 17+00 Lt. Generally stable cut slope, but extensive sloughing of less resistant units is occurring.
10/16/74

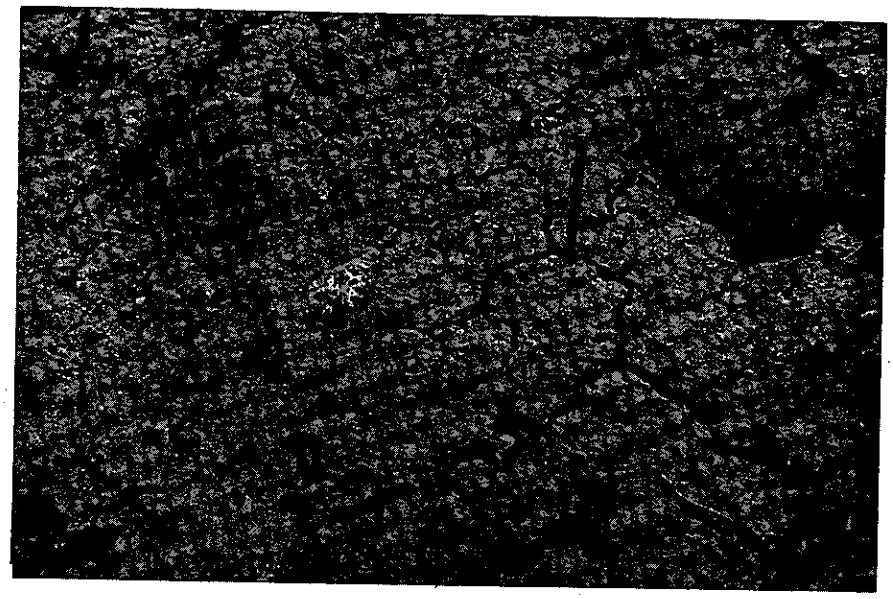


Photo 11

Sta. 15+00 to 17+00 Lt. Close-up of expansive mudstone which sloughs extensively.
12/11/73

Photo 12

Sta 18+00 to 23+00 Rt. Cut slope failure shortly after construction.
2/6/73

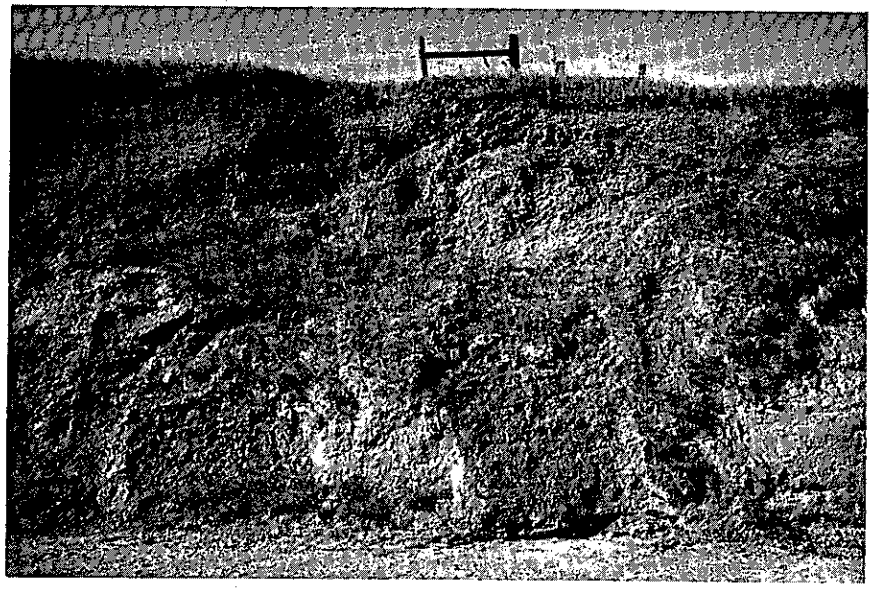


Photo 13

Sta. 18+00 to 23+00 Rt. Same view as Photo 12 as it looked 4 years later.
4/7/77

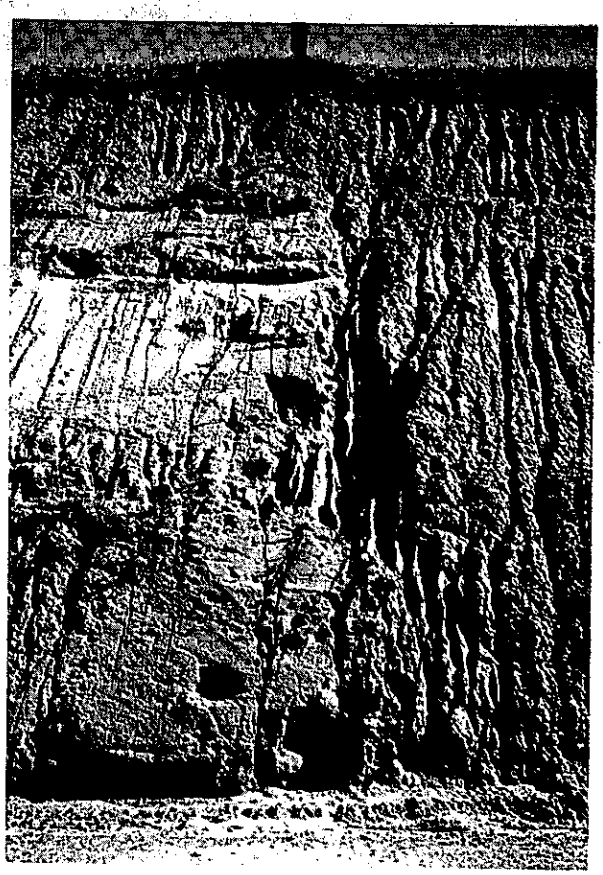


Photo 14

Sta. 18+00 to 23+00 Lt. Erosional fluting in sandy siltstone.
4/7/77

Photo 15

Sta 18+00 to 23+00 Lt. Gullying in clayey siltstone.
8/28/75

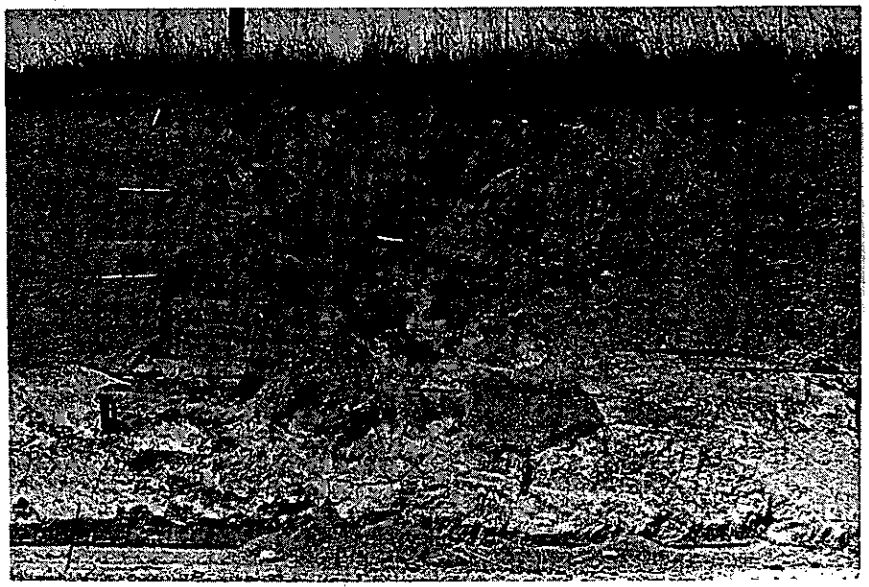


Photo 16

Sta. 25+50 Rt. Slide scarp after debris has been removed.

6/14/73

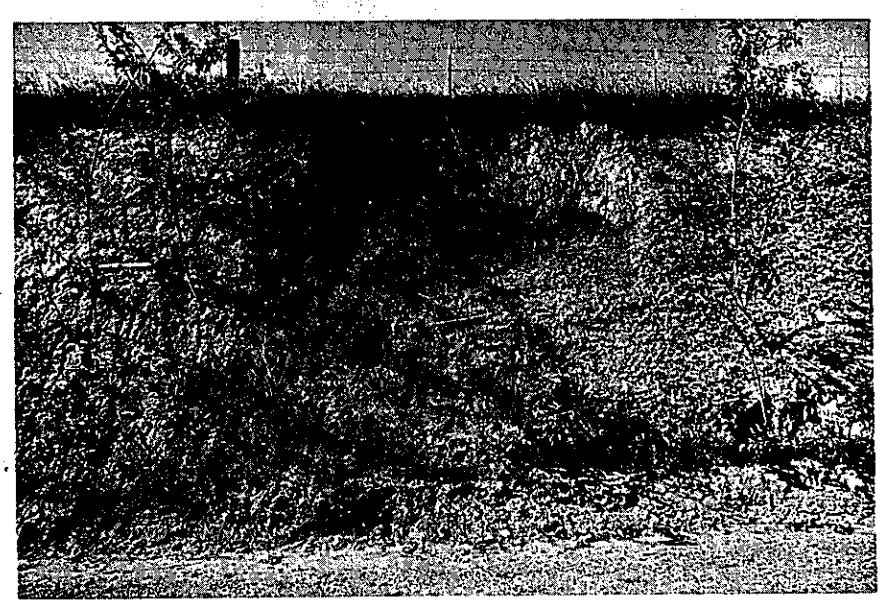


Photo 17

Sta. 25+50 Rt. Same slope as Photo 16 as it looked 4 years later.

4/7/77

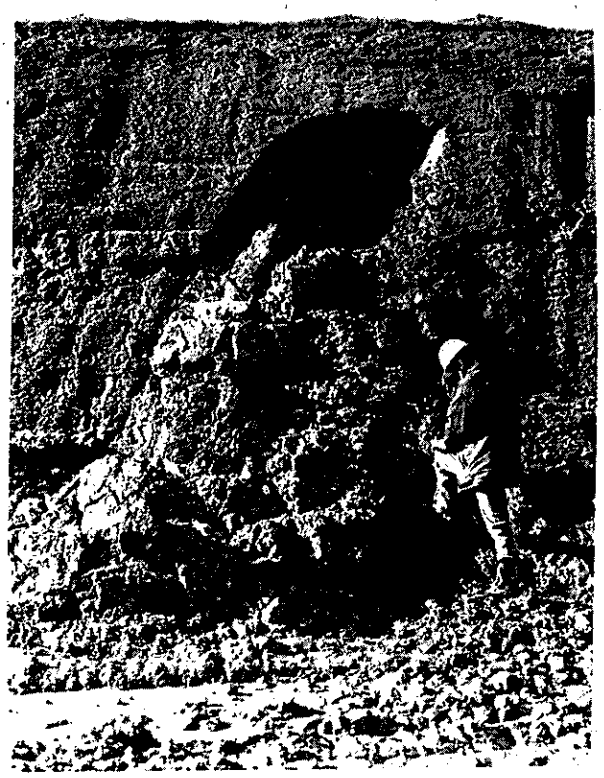


Photo 18

Sta. 27+00 Rt. Small popout.
2/6/73

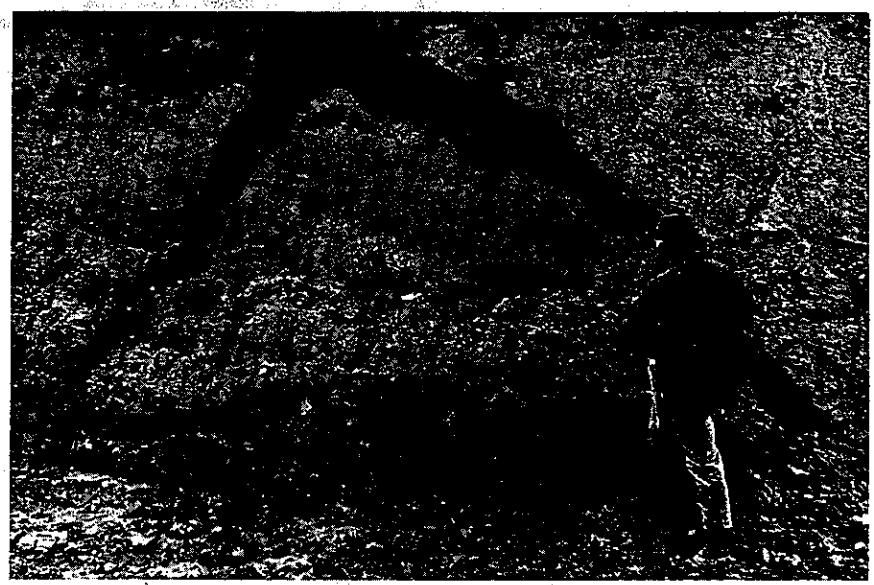


Photo 19

Sta. 26+50 Rt. Small failure.
12/12/72

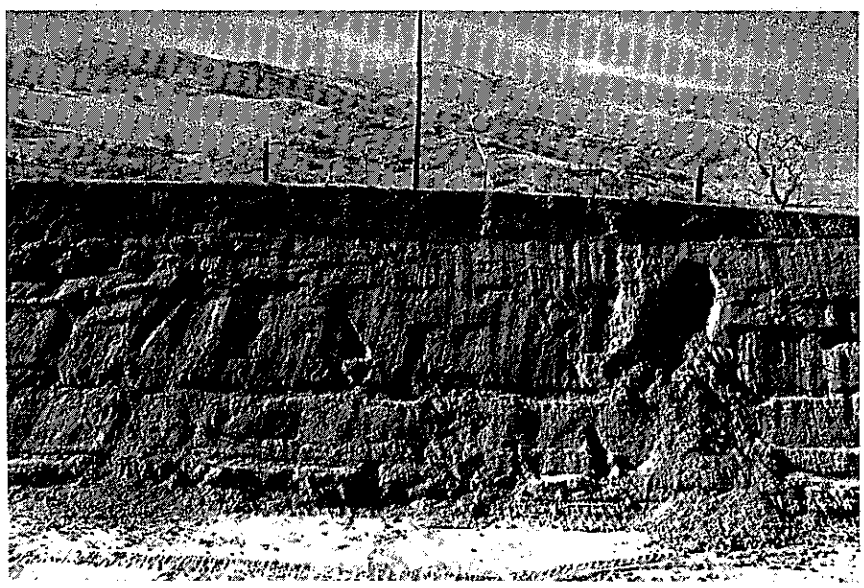


Photo 20

Sta. 28+00 Rt. Small popout and beginning of two more. Note absence of gullys on north facing slope.
2/6/73

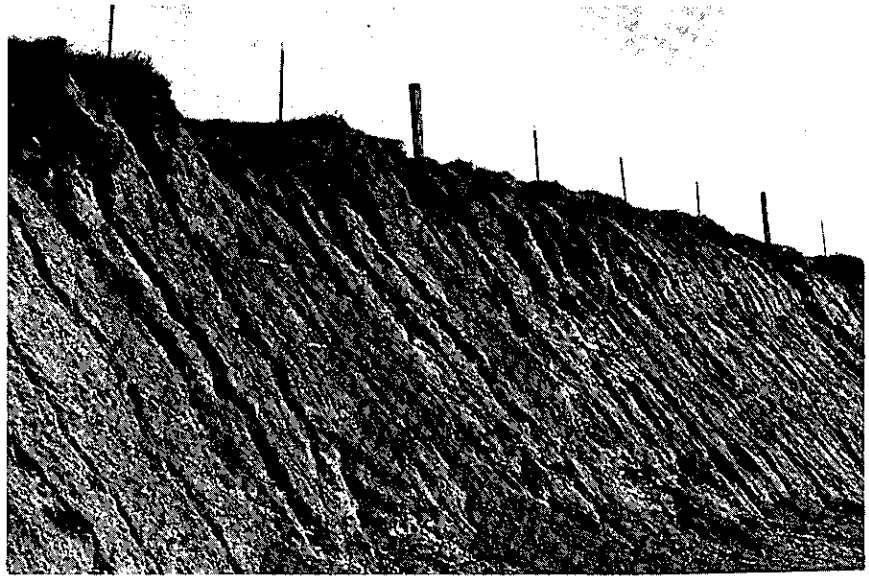


Photo 21

Sta. 28+00 Lt. Development of gullying on south facing slope. Similar material (clayey siltstone) as Photo 20.
2/16/73

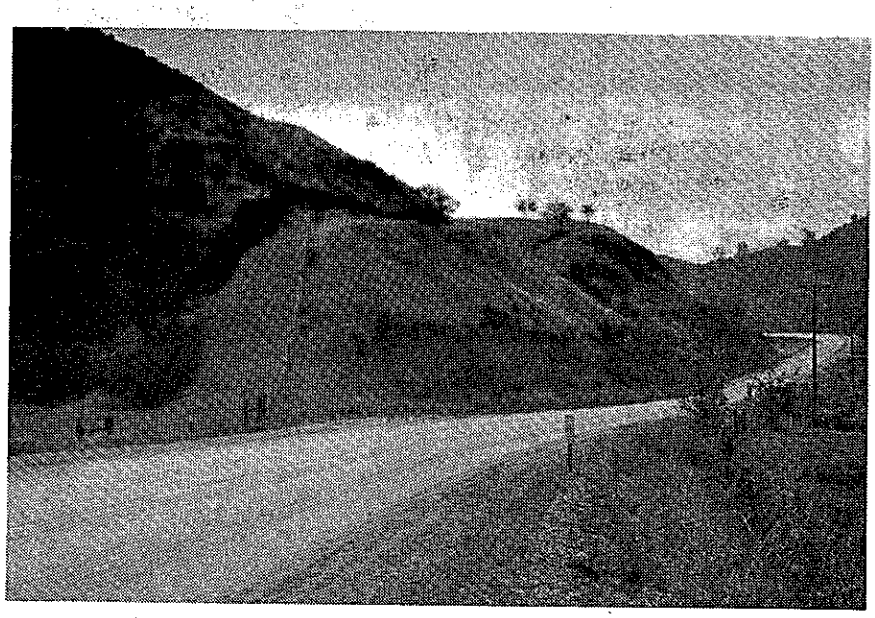


Photo 22

Sta. 44+00 to 47+00. Minor 3/4:1 cut slope showing some sliding and erosional effects.
4/7/77

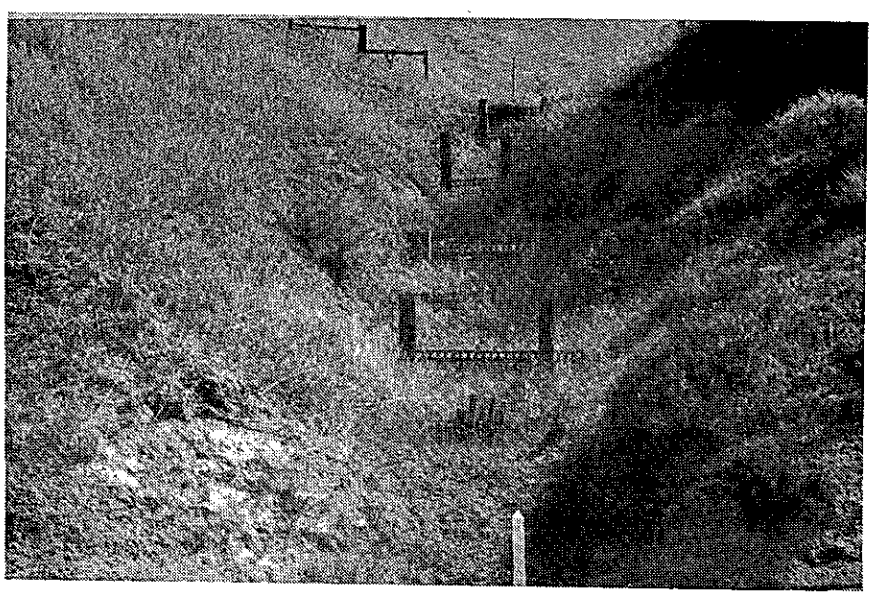


Photo 23

Sta. 47+75. Old aircraft landing mats used in gully to curb erosion.
4/7/77

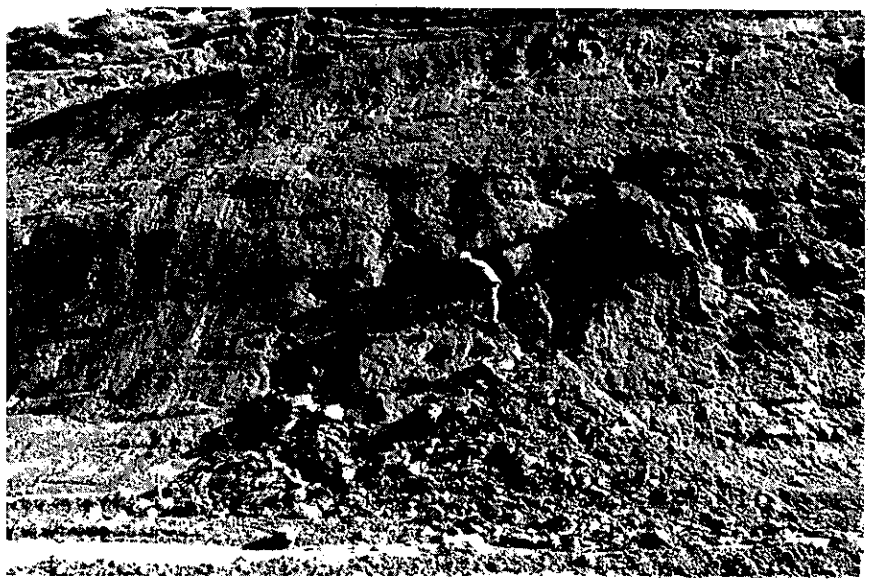


Photo 24

Sta. 50+00 to 52+50 Lt. Beginning of bedding plane failure.
2/6/73

Photo 25

Sta. 50+00 to 52+50 Lt. Taken 10 days after Photo 24. Note progressive failure upslop and also above bench.
2/16/73

Photo 26

Sta. 50+00 to 52+50 Lt. Taken 4 years after Photo 25. Note extensive failure above and below the bench.

4/7/77

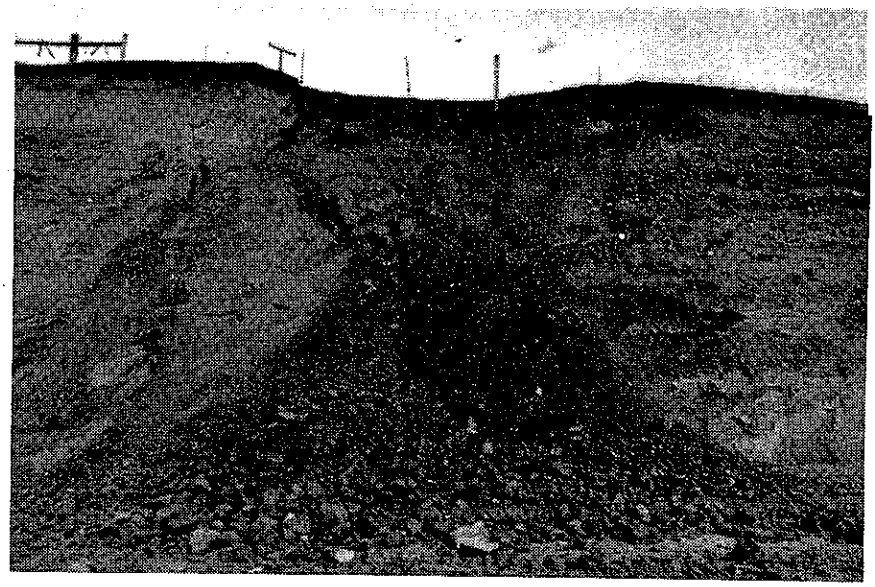


Photo 27

Sta. 65+75. Failure of pocket of gravel near top of cut.
12/12/72

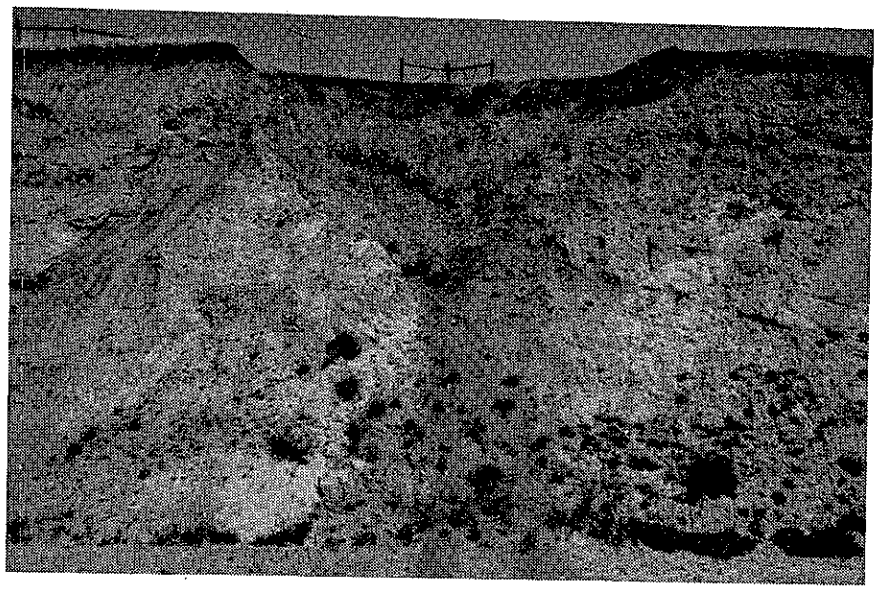


Photo 28

Sta. 65+75. As it looks in 1977.
4/7/77

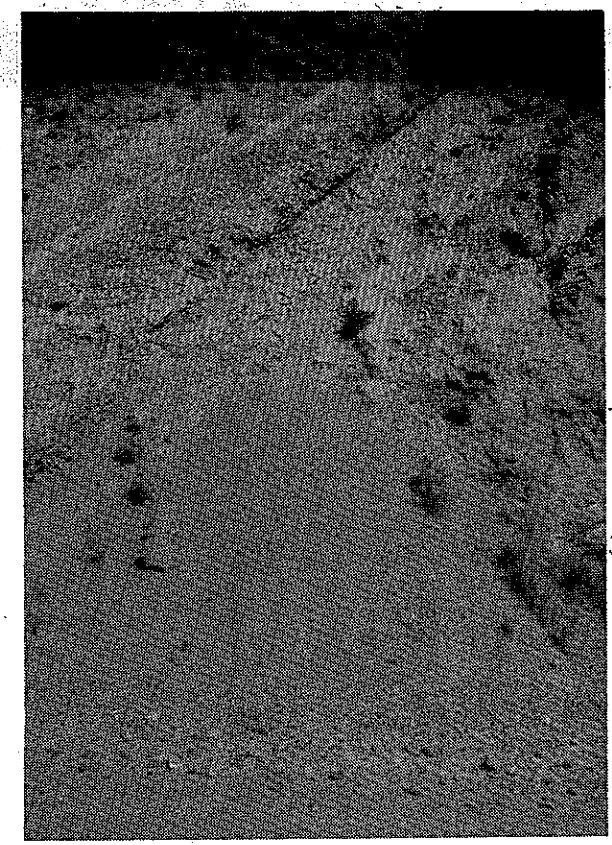
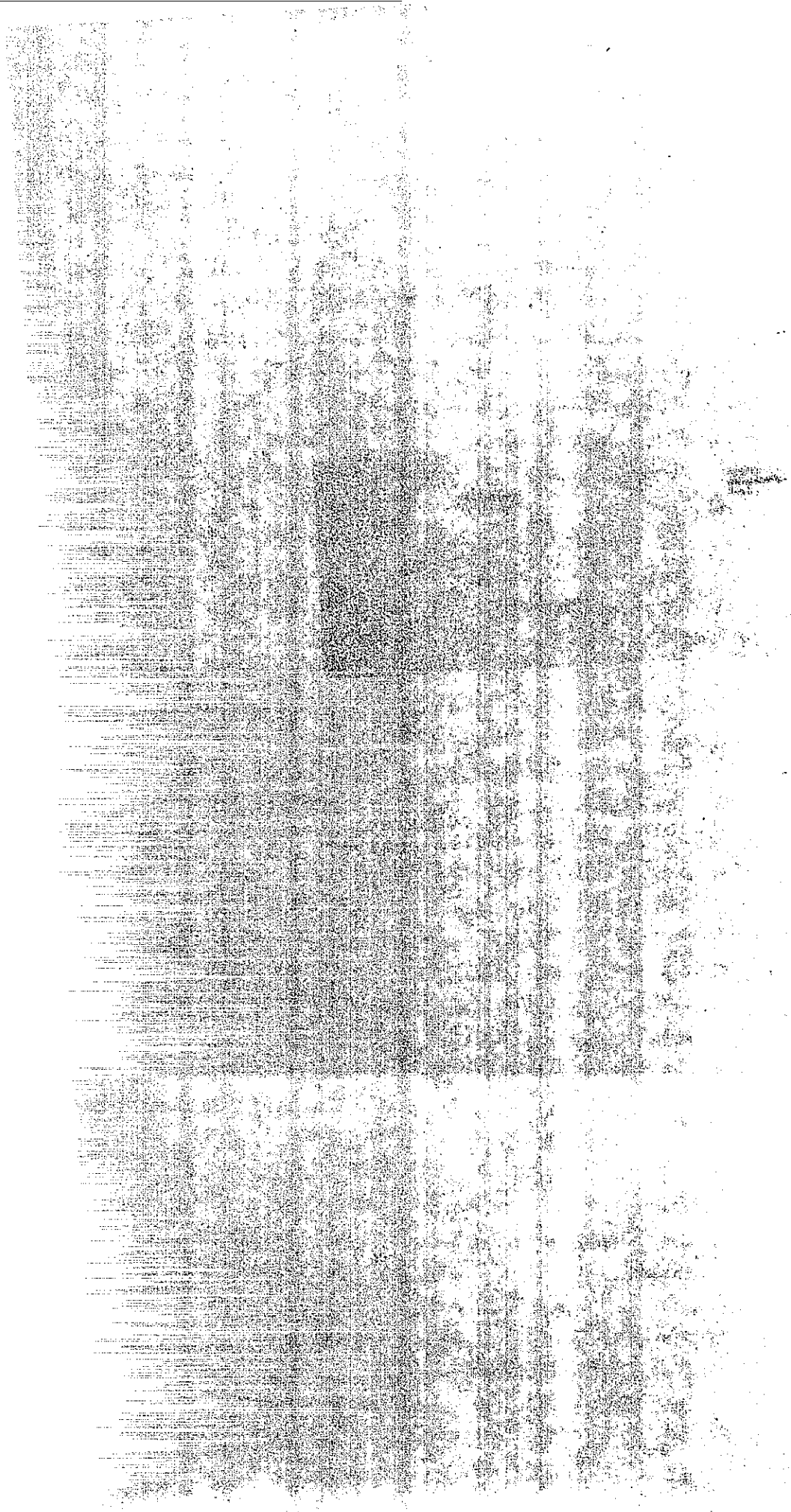


Photo 29

Sta. 66+50. Raveling of blue clay stone member of San Benito Gravels.
4/7/77

Photo 30

Sta. 67+00 to 70+00. These failures occurred shortly after construction and are still active.
2/6/73



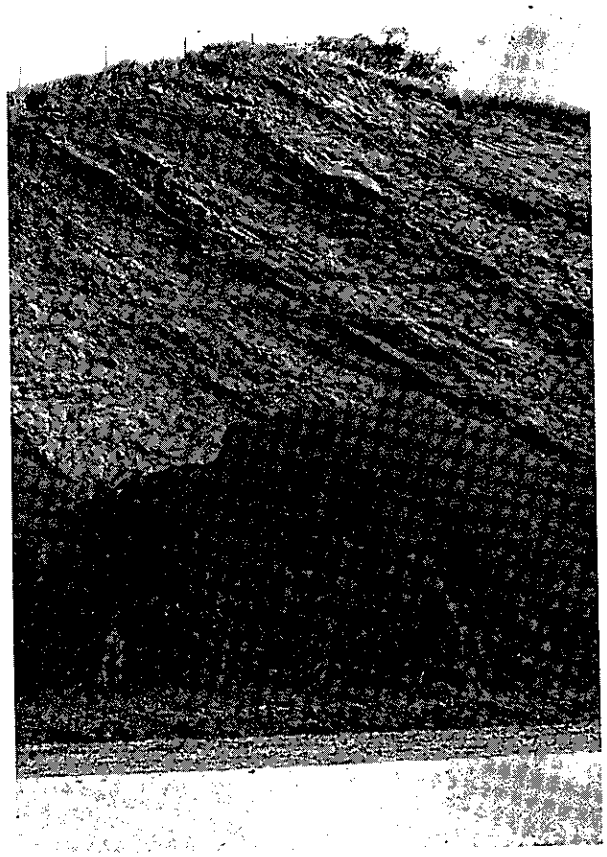
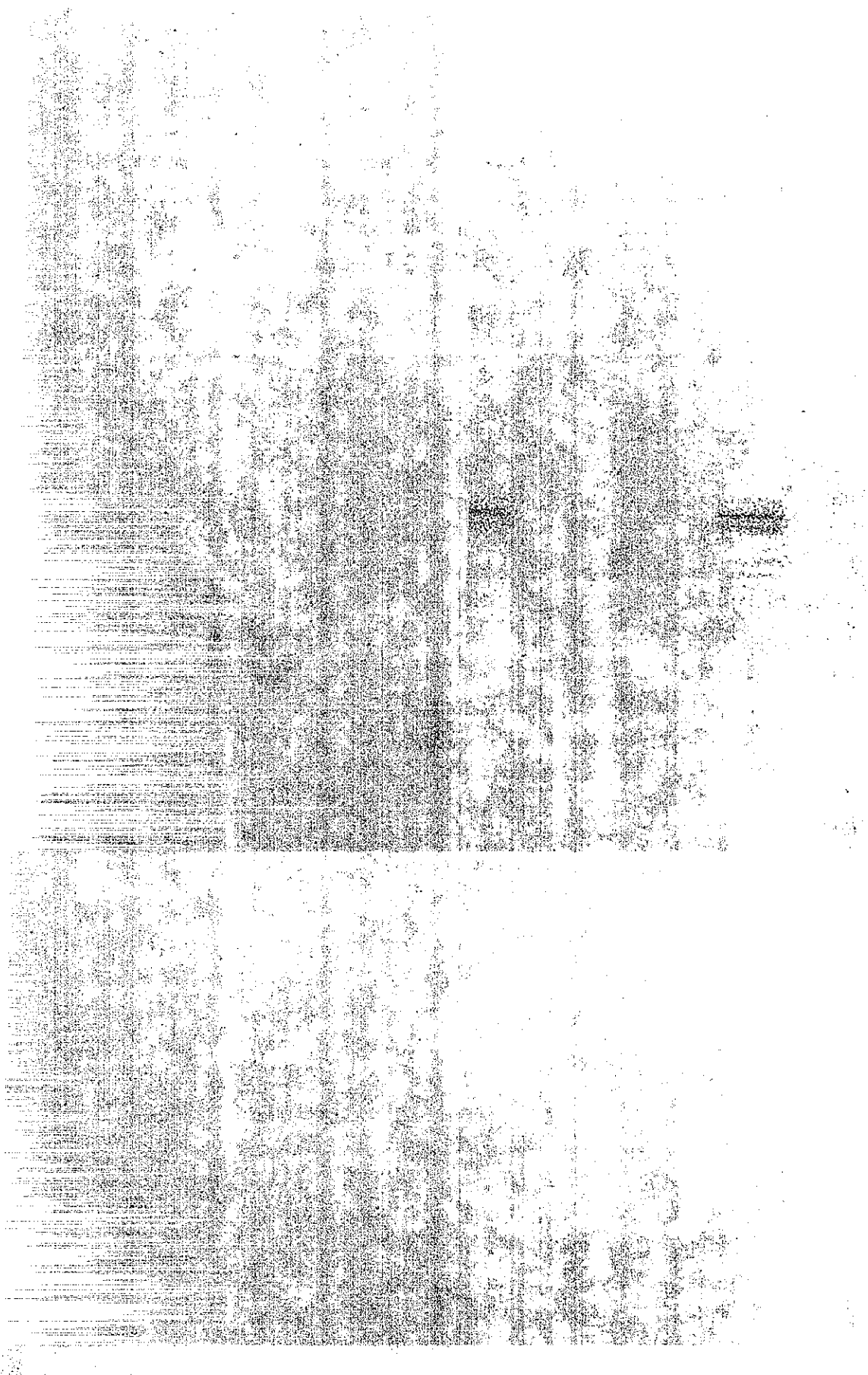


Photo 31

Sta. 91+00 to 94+00. Dipping Sedimentary Units are basically stable but extensive raveling has occurred.
4/10/74



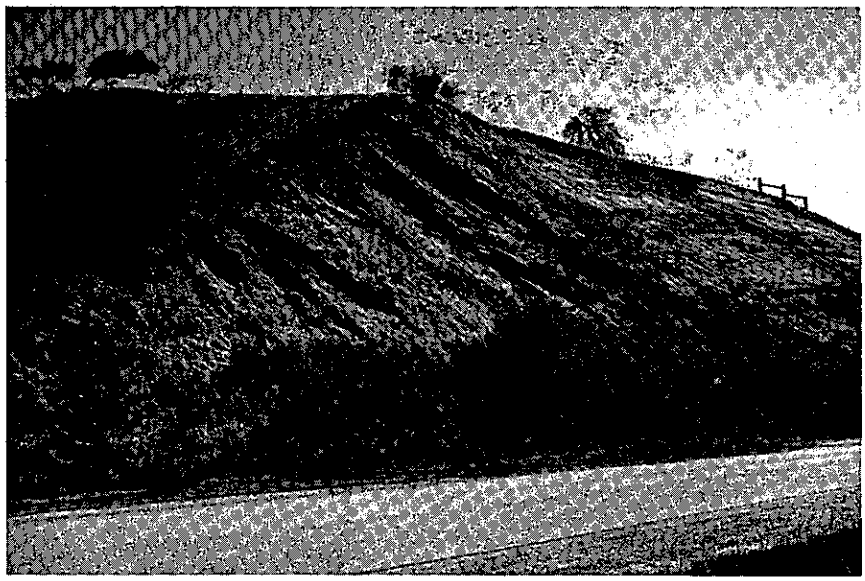


Photo 32

Sta. 91+00 to 94+00. Rate of Raveling has been reduced to the point that some vegetation is growing on the talus slope.
4/7/77

Photo 33

Sta. 142+00 to 147+00. Failure of initial 3/4:1 cut slope.
6/14/73

Photo 34

Sta. 142+00 to 147+00. Slope laid back to 1 1/2:1. Note failure in middle of cut.
4/7/77

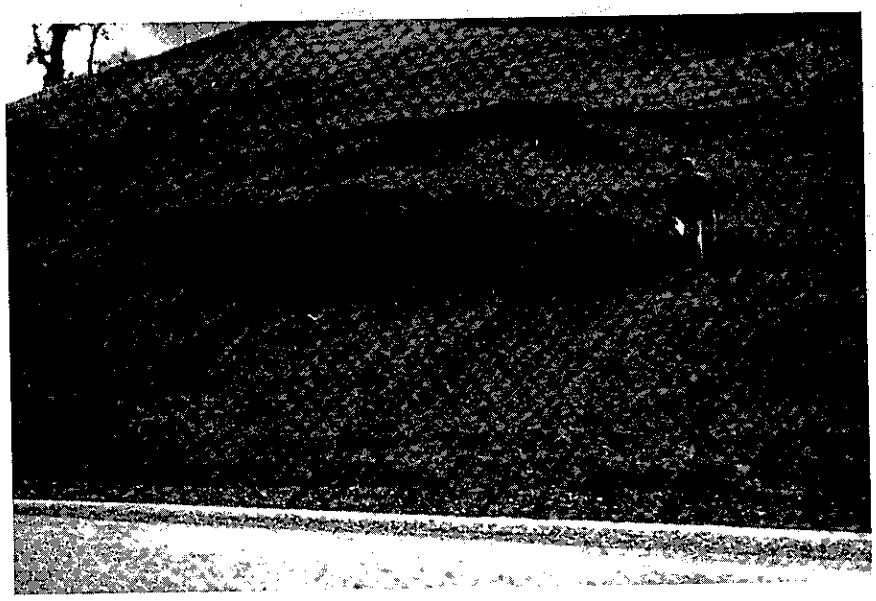


Photo 35

Sta. 142+00 to 147+00. Close up of failure shown in Photo 34. Note dipping clay seam on which man is standing.
2/13/75

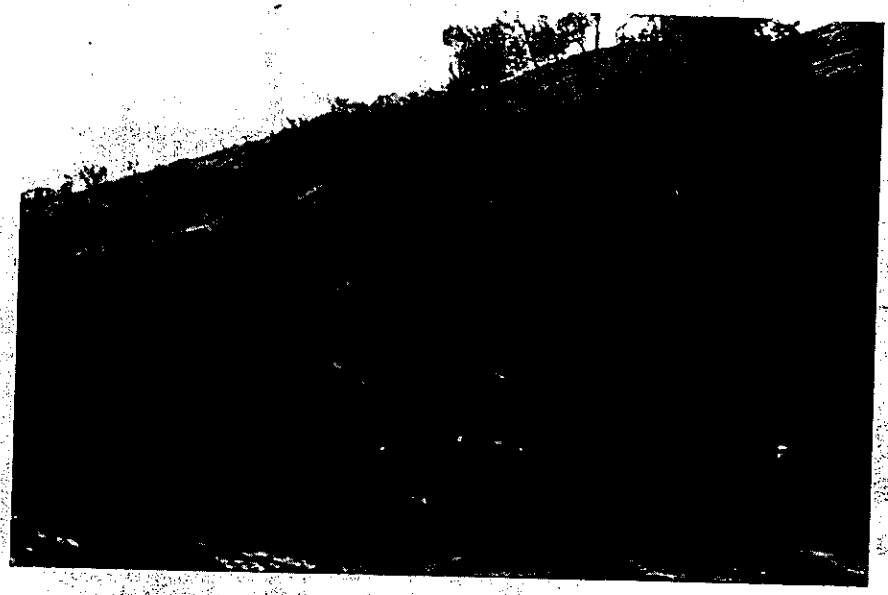


Photo 36

Sta. 188+00 to 192+00. Initial 3/4:1 slope partially constructed.
12/12/72

Photo 37

Sta. 188+00 to 192+00. Slope as it appeared 2 years later with the slide debris removed.
10/16/74

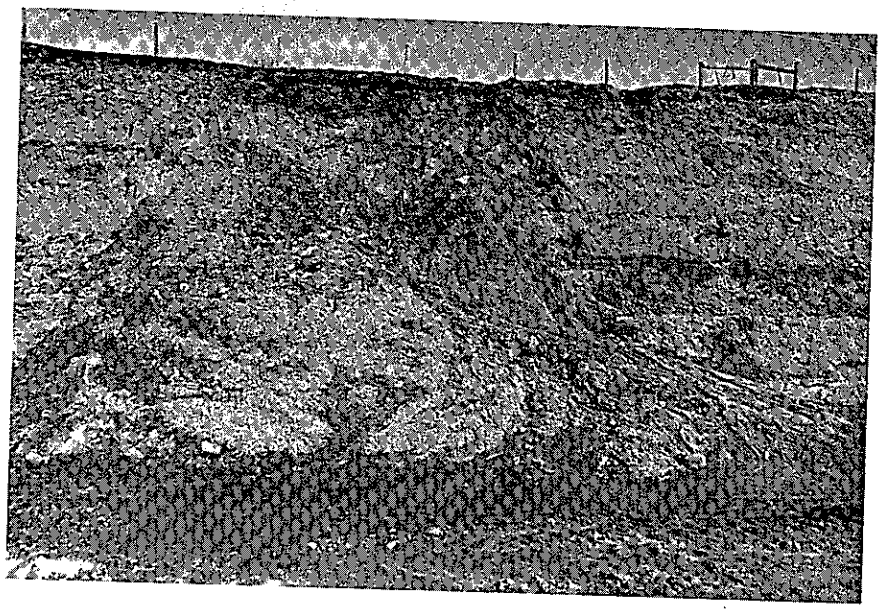


Photo 38

Sta. 211+00 Lt. Minor failure of gravelly lens in stepped slope.
2/16/73

Photo 39

Sta. 208+00 to 213+00 Lt. Stepped cut slopes.
12/9/76

Photo 40

Sta. 239+00 to 245+00. Small failures shortly after construction.
2/6/73

Photo 41

Sta. 239+00 to 245+00. Photo taken 4 years later of same cut slopes. Note gravels on left performed better than the sheared shale on the right.
4/7/77

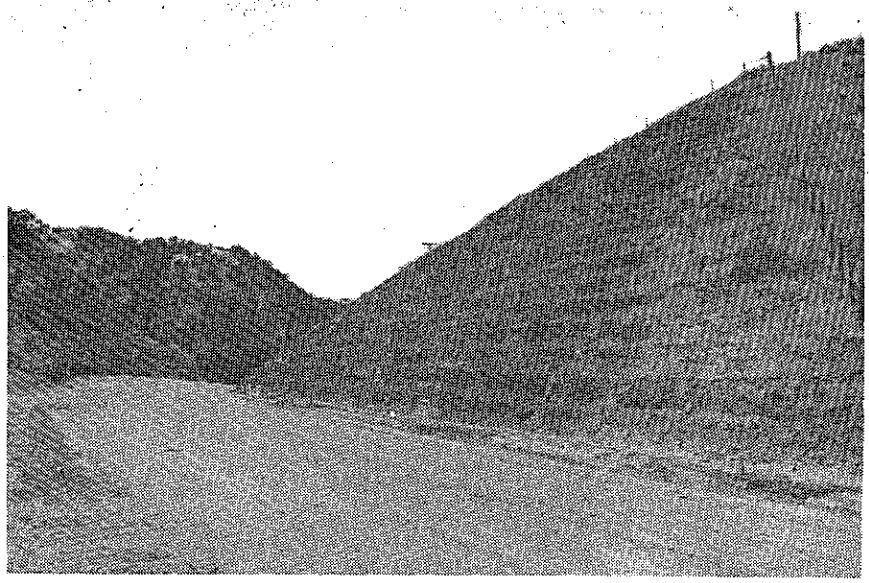


Photo 42

Sta. 262+00 to 267+00. Looking down station at stepped slope.
6/14/73

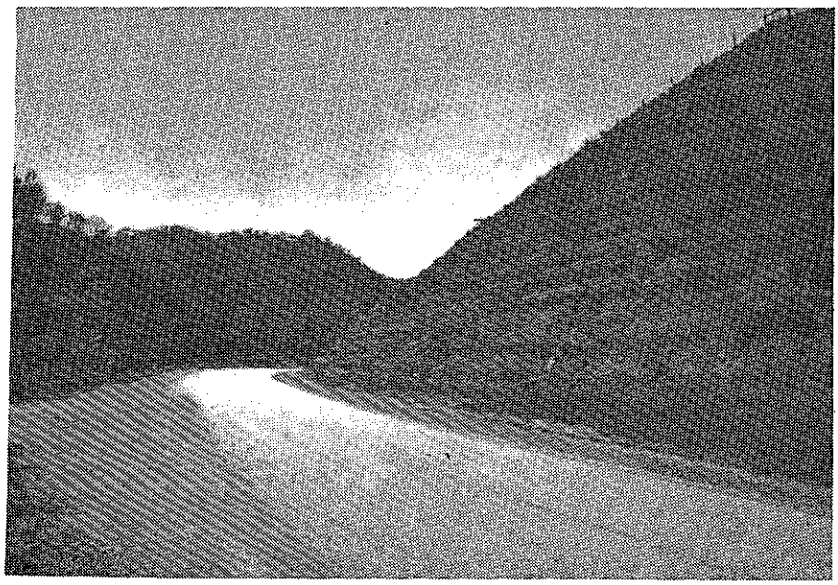


Photo 43

Sta. 262+00 to 267+00. Same view 4 years later. Very little change.
4/7/77

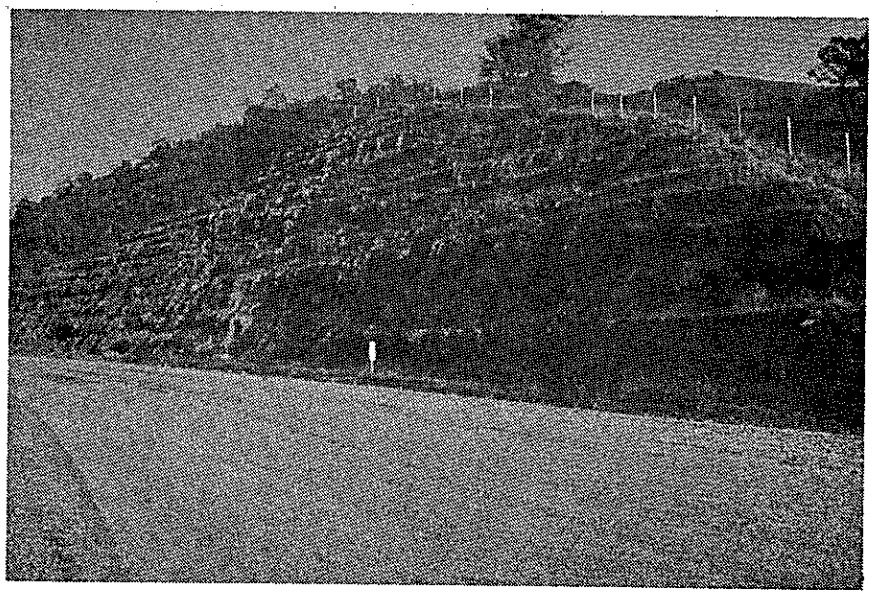


Photo 44

Sta. 262+00 to 267+00 Rt. Stepped cut slope.
12/9/76

Photo 45

Sta. 265+00 Rt. Close-up of stepped slope.
12/9/76

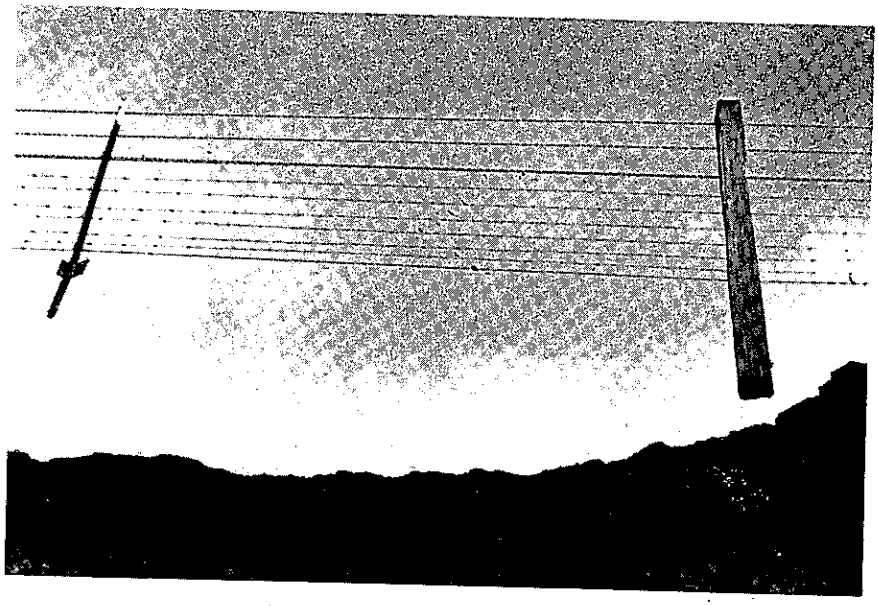


Photo 46

Sta. 65+75 Lt. Fence posts suspended in air by small slope failure.
12/12/77

Photo 47

Sta. 66+ Lt. Corner post exposed by slope excavation.
12/12/77

Photo 48

Sta. 145+00. Top of cut. Note cracking and position of fence relative to edge of cut.

2/16/73